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ANALYSIS OF WORK TIME DISTRIBUTIONS FOR A SHORT CYCLE MANUAL OPERATION

A THESIS

Presented to

the Faculty of the Graduate Division

by

George H. Taft

In Partial Fulfillment

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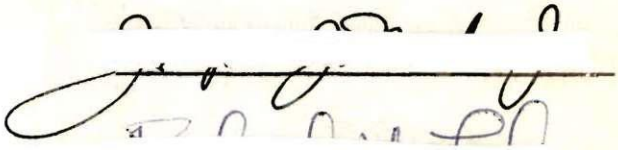
ANALYSIS OF WORK
TIME DISTRIBUTIONS
FOR A SHORT CYCLE
MANUAL OPERATION

Approved:



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ABSTRACT

This thesis attempts to answer some of the questions concerning the effect of variables on the cycle time distribution. Several of the variables in a short cycle manual operation have been analyzed in order to determine:

1. The characteristics of the cycle time distribution with all variables included.
2. The characteristics of the cycle time distribution with certain variables removed.

Micromotion analysis of 15,000 feet of film was performed to obtain data on nineteen different operators on three shifts, performing a short cycle manual operation.

From the results of the micromotion analysis, it was found that major variations in methods appeared in the first and last elements of the operation. The overall cycle time containing the variations was termed "gross cycle time," and the portion of the cycle not affected by the variation in method was termed "modified cycle time." Distributions for the various cycle times was prepared.

With consideration of the limiting factors mentioned, the following conclusions were drawn:

1. The individual operator modified cycle time distributions with variables included tend to be positively skewed.
2. The shift distributions with variables included and variables excluded are positively skewed.

3. The distributions of all shifts combined with variables included and variables excluded are positively skewed.

4. The modified cycle time distribution, with variables included and variables excluded, approximate a straight line relationship, when the log of the cycle time was plotted on probability paper; thus the distributions can be approximated by a log normal curve.

5. Variables selected and eliminated within the work cycle did not significantly alter the characteristics of the modified cycle time distribution.

It is recommended that a similar but more detailed micromotion study be made classifying the variables within the individual elements. A study of this nature should isolate many of the assignable causes of variation within the work cycle.

CHAPTER I

INTRODUCTION

This work is Part II of a project sponsored by the Georgia Institute of Technology Research Committee under the direction of Doctors R. N. Lehrer and J. J. Moder.

Previous Work

The first segment of the project was undertaken by Mr. Warren Lind, and was reported in his Master's Thesis entitled "A Statistical Analysis of Work Time Distributions," presented to the Graduate Division in July 1953.

Mr. Lind performed a stop watch study on the same operators performing the same work as those included in the present study.

In the first study a representative sample of cycle times for each operator was desired. It was decided that a sample of 25 cycles would be observed as often as possible in the before and after lunch periods of the three shifts. A split second hand decimal stop watch was used to determine the cycle times. The data were recorded to the nearest hundredth of a minute.

When recording the data the following notations were made:

DP - Drop part
BP - Bad part
GP - Get part
MP - Move part
AD - Advoidable delay
S - Turn cap to inspect finished part
I - Inspect parts or unit

CM - Change method
RP - Release parts

An "x" was placed on the data sheet adjacent to the cycles containing deviations from the standard procedure. Only cycles which contained one of the extraneous elements mentioned above were eliminated. This procedure required a decision during the cycle as to whether the delay encountered should be extraneous, thus eliminating the cycle from the analysis.

Each period sample of twenty-five observations was broken into five subgroups of five observations each, so that a period sample contained five consecutive subgroups each containing five observations.

From the data collected the following questions were posed:

1. Do operators follow any one pattern of performance, or a work curve throughout the day?
2. Do unadjusted performance times tend toward any formal distribution or could they be made to form any model?
3. Are operators' cycle times statistically stable?
4. What is the relationship of variation without a period to the relationship between periods?

In the study nearly 3200 observations were made, and these observations were analyzed statistically using control chart procedures.

As the result of the analyses, the following conclusions were drawn:

1. The operators on this operation did not follow any particular work curve.
2. The unadjusted performance times tended to form a positively skewed distribution.
3. The performance times of sixteen out of nineteen operators were not statistically stable.
4. The variation within a period was significantly greater than the variation between periods.

5. Stop watch performance time data do not give sufficient information to separate chance causes from assignable causes of variations.

Present Study (Part II)

This part of the study was primarily concerned with conclusion number 5 of the previous study. Micromotion study was used in an effort to determine the effects of some of variables on the cycle time distribution.

Fifteen thousand feet of film of the same operators mentioned in the previous study were taken and analyzed in order to classify some of the variables. Variables used in the analysis were selected on the basis of frequency of occurrence among the operators.

It is not within the scope of this thesis to classify every variable affecting the work situation. However, it is felt that variables selected do represent some of the major causes of variation.

CHAPTER II

OBJECTIVE

The purpose of this thesis is to study a short cycle manual operation in order to determine:

1. The characteristics of the cycle time distribution with all variables included.

2. The characteristics of the cycle time distribution with certain variables removed.

CHAPTER III

PROCEDURE

General Conditions

The operators studied were occupied in the assembly of a ball point pen. They were not on an incentive system of wage payment. However, they were expected to produce between four and five thousand units per day.

The actual work time varied among the three shifts. The first shift worked 7.83 hours, second shift 7.75 hours, and third shift 6.9 hours. Operators on the third shift had relatively little supervision compared to the other two shifts.

The average production rate and experience of the operators studied was:

Operator	Averate Production in Units Per Hour	Experience in Months
First Shift		
1	485*	6
2	527	10
3	528	9
4	500	10
5	449	10
6	306**	1/2
7	526	10
Second Shift		
8	421	6
9	441	10
10	516	10
11	491	6
12	418	8
13	430	10

Operator	Average Production in Units Per Hour	Experience in Months
Third Shift		
14	448	10
15	557	7
16	578	8
17	578	10
18	578	10
19	479	5

* Production data rounded off to nearest 5 units.
** Data excluded from distributions because of lack of experience.

Company records revealed that a worker can reach the level of maximum production in two months.

The general working conditions were clean and well lighted, ventilated and pleasant in appearance. Operators often talked and joked with each other and seemed to be in good spirits.

Taking Motion Pictures of The Operation

The camera was positioned to the right of each operator at an angle of about forty-five degrees. Operators on the first shift were photographed seven times for two minute intervals. The second and third shifts were photographed six times. An effort was made to take pictures at times distributed throughout the shift.

The Camera.--Pictures were taken with an Eastman Kodak Cine Special II Camera, equipped with a 15 millimeter, f-2.5 lens and driven by a synchronus motor at 2000 frames per minute.

Positioning the Camera.--The camera was carefully positioned at each work station before the pictures were taken. To hasten the initial camera locating, the base was outlined on the floor in chalk next to each work place.

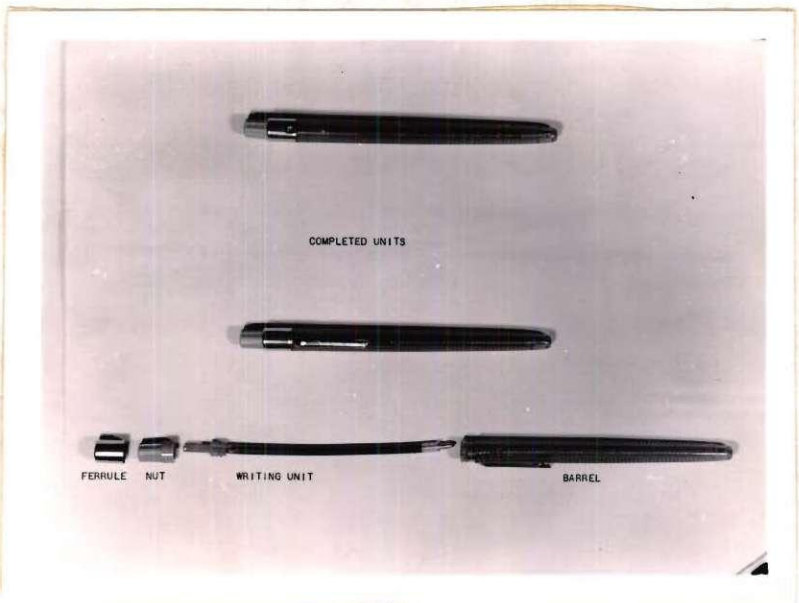


Figure 1. Ball Point Pen Parts

After the camera was placed in the location marked on the floor, it was aimed visually and the distance from the camera lens to the center of the layout was measured. As a result, all the pictures have a uniform prespective of the workplace and motions.

Motion Picture Identification.--Pictures were identified by holding a blackboard containing the information in front of the camera at the beginning of each shot.

The Log Book.--A log book was kept during the entire picture taking operation. Information was recorded while the pictures were being taken. An entry for an operation contained: (1) shift number, (2) operator's name, (3) time particular shot was taken, (4) film roll number, and (5) remarks. Notations were made in the remarks column if they would aid in the analysis.

Film Analyses

Elemental Breakdown.--The work cycle was broken down into twelve elements of "get" and "place." Each element was then broken down into therbligs and the end points were defined. The elements, therbligs and end points were:

Element	End Point
1. Get Barrel (Fig. 2-1) TE, ST, and G.	The frame before the frame where the hand begins to move with the barrel.
2. Place Barrel (Fig. 2-2) TL, P, A and RL.	The frame before the frame where the hand begins to move without the barrel.
3. Get Writing Unit (Fig. 2-3) TE, ST and G.	The frame before the frame where the hand begins to move with the writing unit.
4. Place Writing Unit (Fig. 2-4) TL, P, A and RL.	The frame before the frame where the hand begins to move without the writing unit

Element	End Point
5. Get Nut (Fig. 2-5) TE, ST and G.	The frame before the frame where the hand begins to move without the drive nut.
6. Place Nut (Fig. 2-6) TL, P, A and RL.	The frame before the frame where the hand begins to move without the nut.
7. Get Ferrule (Fig. 2-7) TE, ST and G.	The frame before the frame where the hand begins to move with the ferrule.
8. Place Ferrule (Fig. 2-8) TL, P, A and RL.	The frame before the frame where the hand begins to move without the ferrule.
9. Get Completed Unit (Fig. 2-9) TE and G.	The frame before the frame where the hand begins to move with the completed assembly.
10. Place Unit (Fig. 2-10) DA, TL and P.	The frame before the frame where the unit enters the staker.
11. Stake Unit (Fig. 2-11) A, H and DA.	The frame before the frame where the unit clears the staker.
12. Aside (Fig. 2-12) TL and RL.	The frame before the frame where the hand loses contact with the completed assemblies.

Although the present study is concerned primarily with cycle time distributions, the detailed breakdown indicated above was used to aid in classifying methods variations within the cycle.

The Projector.--A Keystone 16 millimeter projector equipped with a frame counter and special control box was used in the analyses. The control box contained a reostat and a directional control switch. This allowed the film to run in either direction at any desired speed.

Physical Analysis.--Fifteen thousand feet of film containing pictures of the 19 operators were analyzed frame by frame. Element end points were determined visually, then recorded in terms of frame number. Variations in elements performed by the right and left hands were also noted. For

example some of the more common elements in get and place barrel were:

Element	Variations	
Get barrel	D in TE	- Delay in transport empty
	Slow in TE	- Slow in transport empty
	D in ST	- Delay in select
	Slow in ST	- Slow in select
	SH	- Search for part
Place barrel	D in G	- Delay in grasp
	RG	- Regrasp
	Fumble in G	- Fumble in grasp
	G 2 parts and ret 1	- Grasp two parts and return one
	D in TL	- Delay in transport loaded
	Slow in TL	- Slow in transport loaded
	RG in TL	- Regrasp in transport loaded
	Tap on table	- Tap unit on table in transport loaded to regrasp part
	D in P	- Delay in position
	Slow in P	- Slow in position
	RG in P	- Regrasp in position
	D in A	- Delay in assembly
	RG in A	- Regrasp in assembly
	RG-C in A	- Contact regrasp in assembly
	RL, TE, G, A and RL in A	- When operator releases barrel and regrasps farther up
	Aside parts	- Operator asides handful of parts
	Get parts	- Operator gets new supply of parts

Similar notations were also made for other elements of the cycle.

1. Get-Barrel

2. Place-Barrel

Figure 2. Assembly Operation

3. Get-Writing Units

4. Place-Writing Unit

Figure 2. Assembly Operation
(Continued)

5. Get-Drive Nut

6. Place-Drive Nut

Figure 2. Assembly Operation
(Continued)

7. Get-Ferrule

8. Place-Ferrule

Figure 2. Assembly Operation
(Continued)

9. Get-Completed Assembly

10. Place-Completed Assembly

Figure 2. Assembly Operation
(Continued)

11. Stake Assembly

12. Aside Completed Assembly

Figure 2. Assembly Operation
(Continued)

CHAPTER IV

EVALUATION OF DATA

Work Place Layout.--Work benches were designed to facilitate simultaneous symmetrical hand motions. Certain fixed equipment was built into the work benches (Fig. 3). In addition to the fixed items in the layout, other moveable equipment was used.

Each operator was allowed to arrange the moveable equipment in a manner which she felt was most convenient. As a result there were eight different layouts used among the nineteen operators.

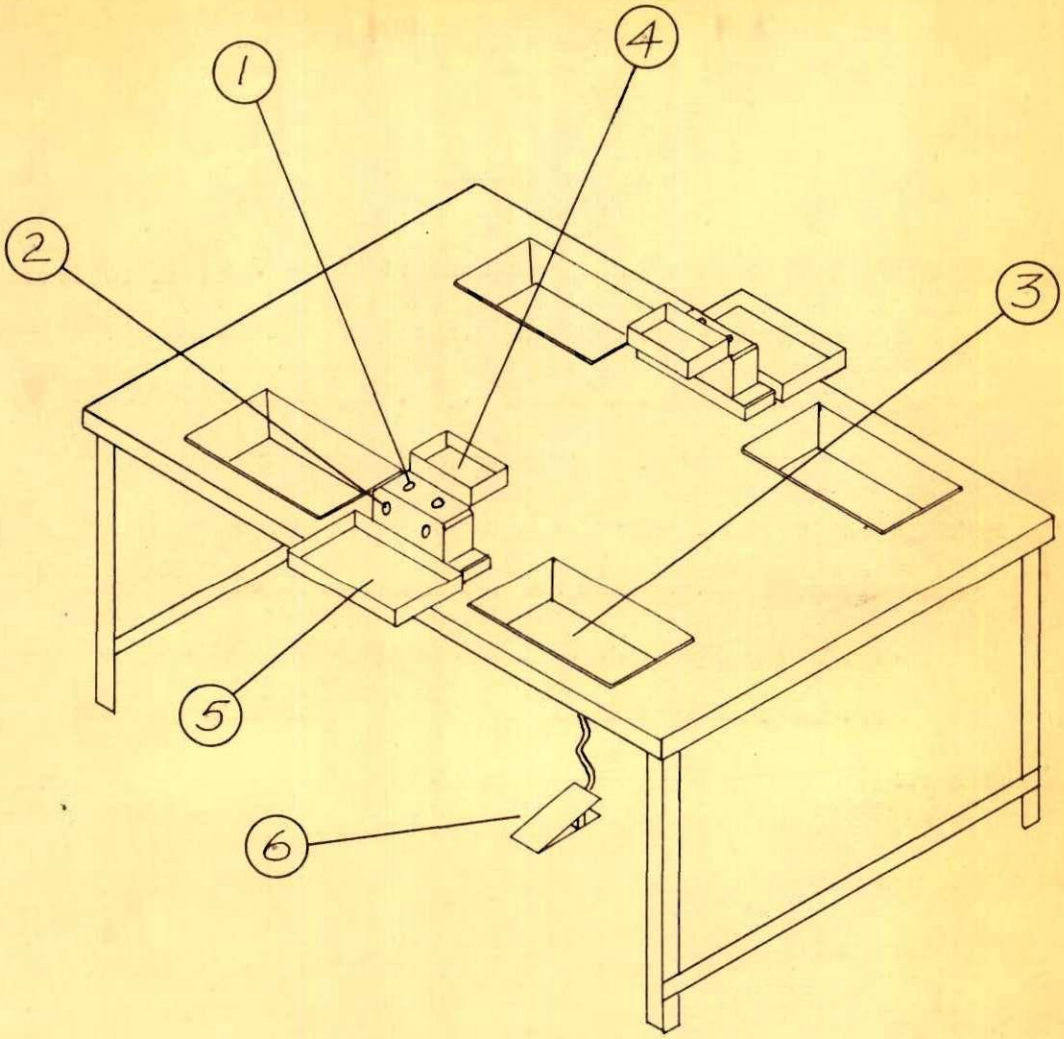
The layouts used by the operators were as follows:

Layout Number	Figure Number	Operators Using Layouts
1	4	1,4,6,9,10 and 12
2	5	7
3	6	3 and 5
4	7	2 and 19*
5	8	8,11 and 13
6	9	14, 17 and 18
7	10	15
8	11	16

* Operator 19 asides the completed assemblies in the ferrule tray. This was not common to other operators using the same layout.

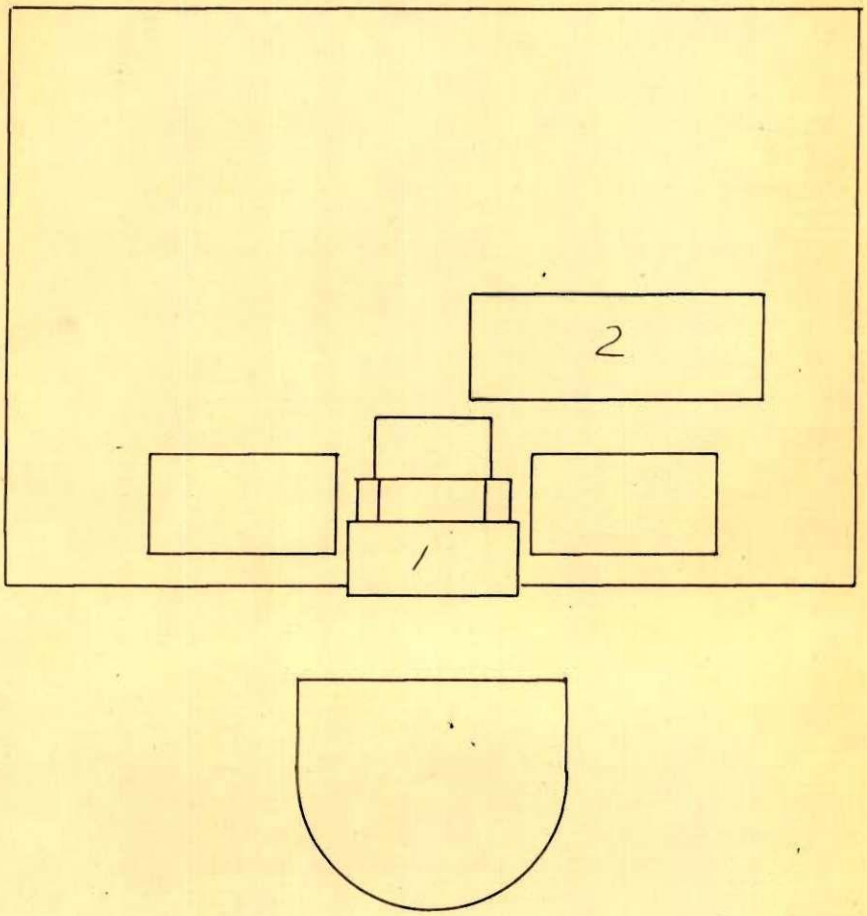
Method.--In conjunction with the different layouts operators used slightly different methods. The differences in method occurred in the first part of the cycle when the operator picked up the barrel and in the last part of the cycle when the operator asided the complete assemblies. The different methods used by the operators were:

Method No. 1 Right-hand and left-hand get barrels in front. Left-hand



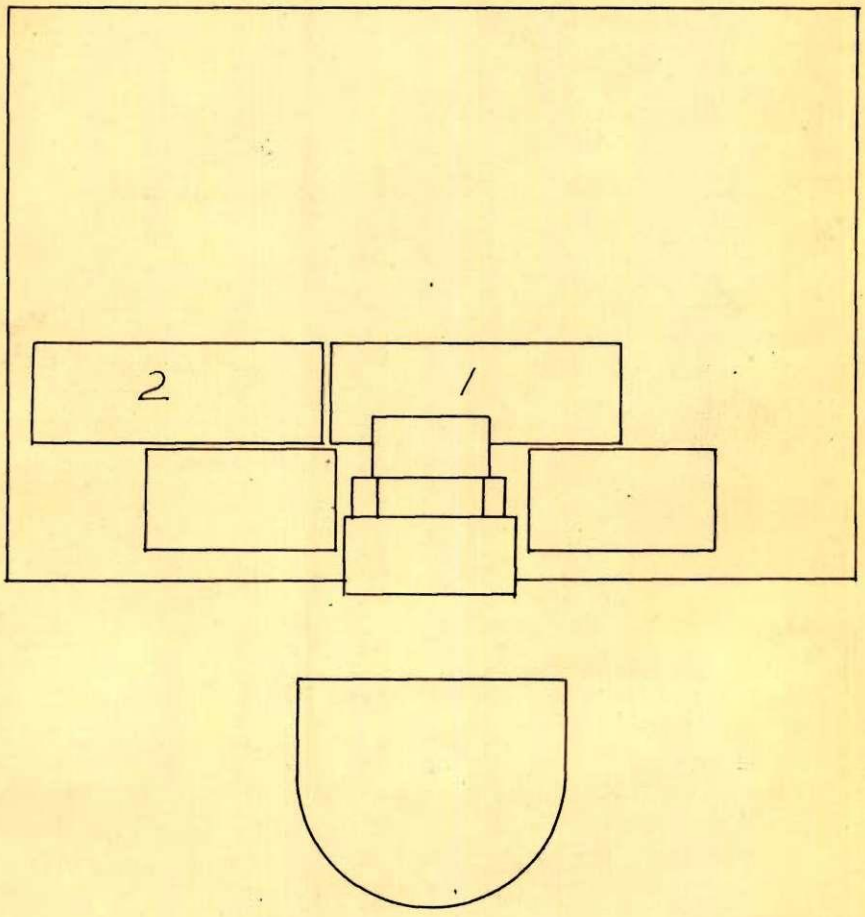
1. Assembly Holding Fixture
2. Staking Unit
3. Writing Unit Tray
4. Drive Nut Tray
5. Ferrule Tray
6. Staker Foot Pedal

Figure 3. - Layout - Fixed Equipment



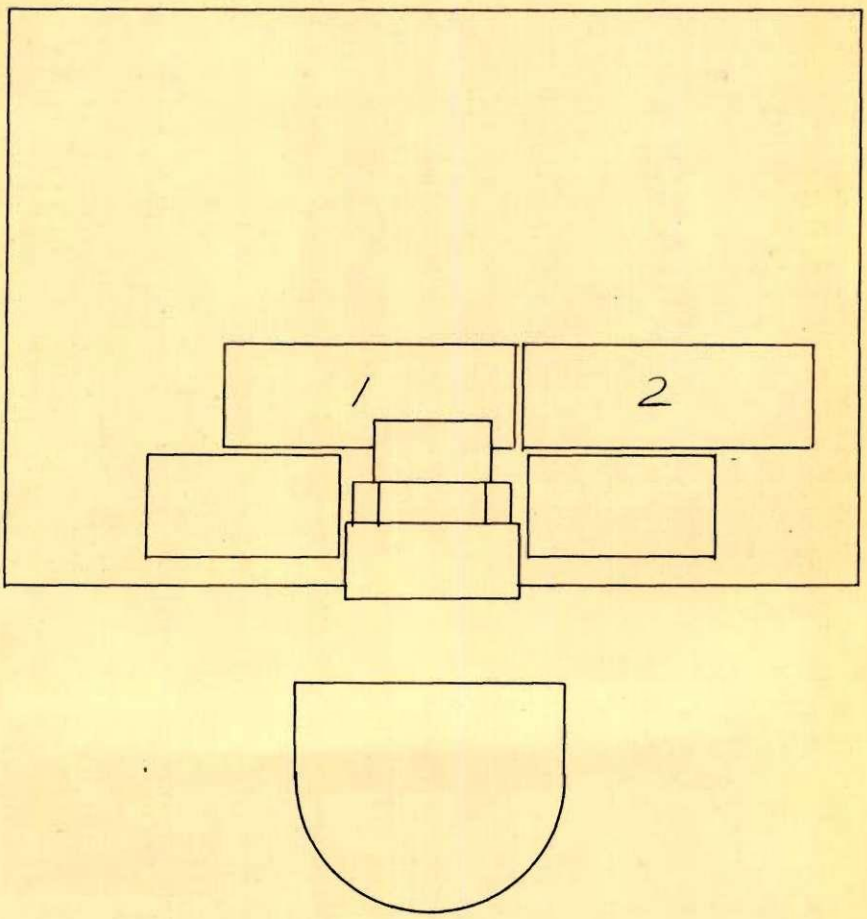
1. Barrels
2. Assembled Pens

Figure 4. - Layout 1 - Moveable Equipment



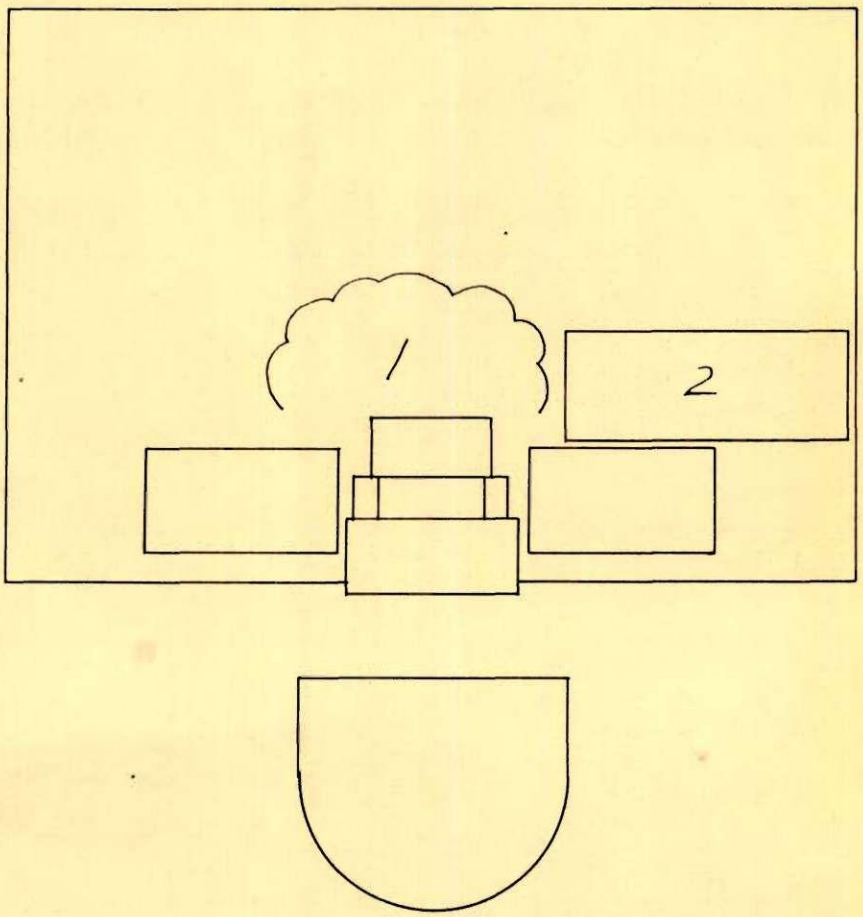
1. Barrels
2. Completed Pens

Figure 5. - Layout 2 - Moveable Equipment



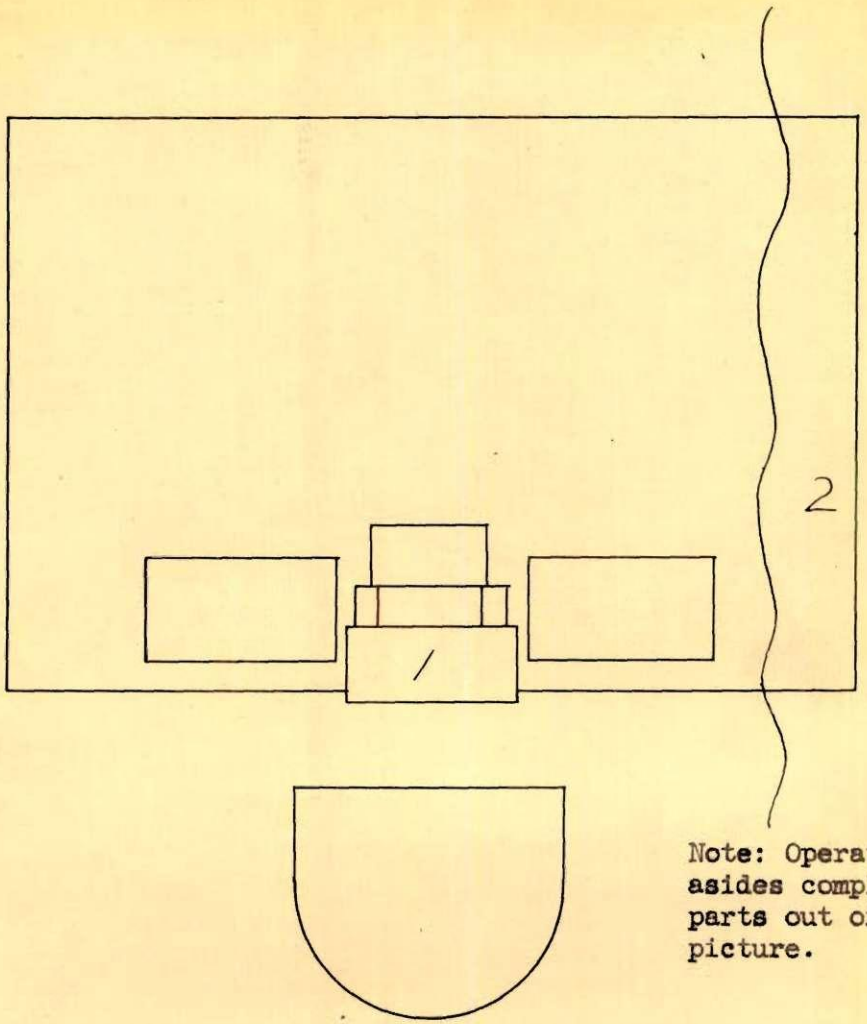
1. Barrels
2. Completed Pens

Figure 6. - Layout 3 - Moveable Equipment



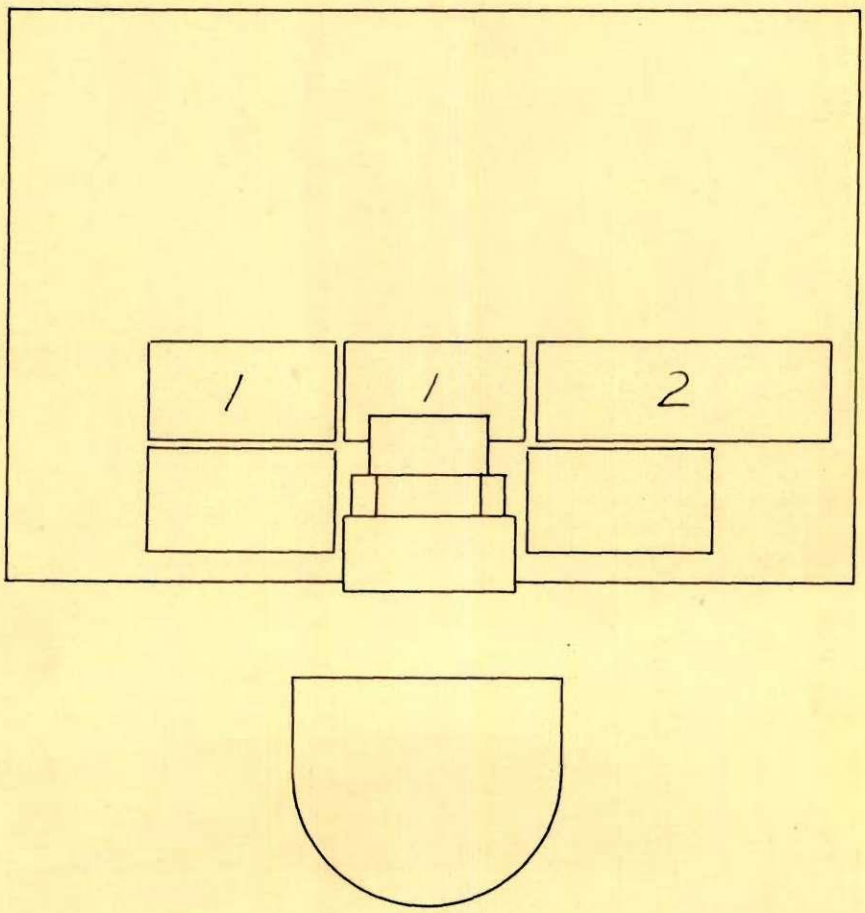
1. Barrels
2. Completed Pens

Figure 7. - Layout 4 - Moveable Equipment



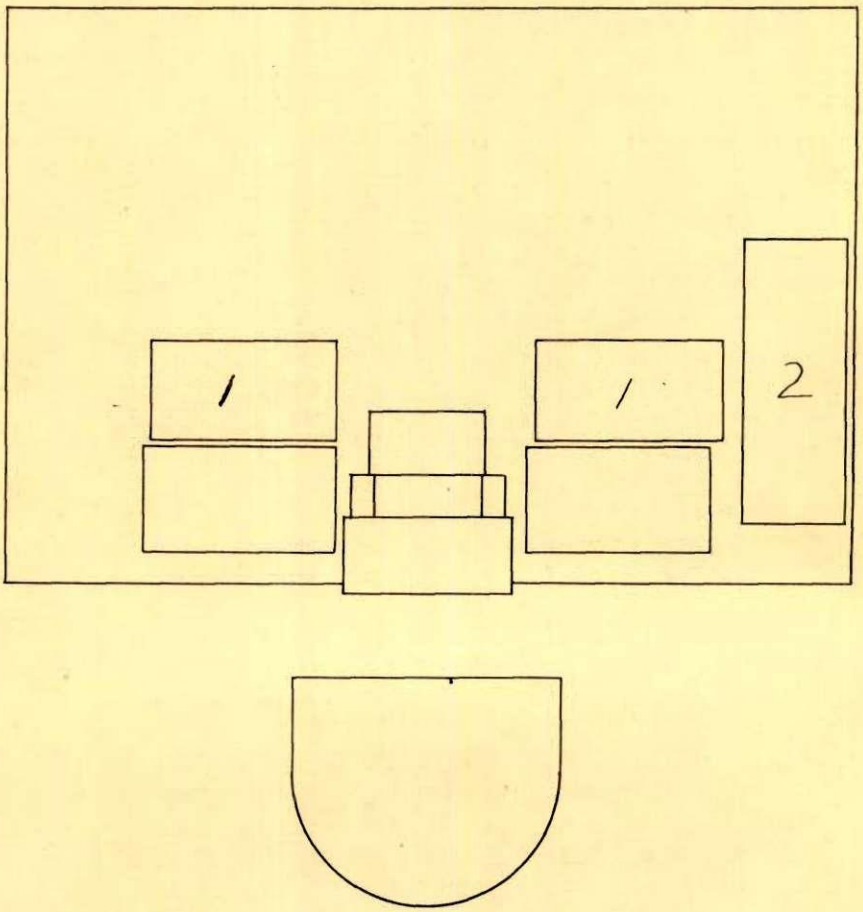
1. Barrels
2. Assembled Pens

Figure 8. - Layout 5 - Moveable Equipment



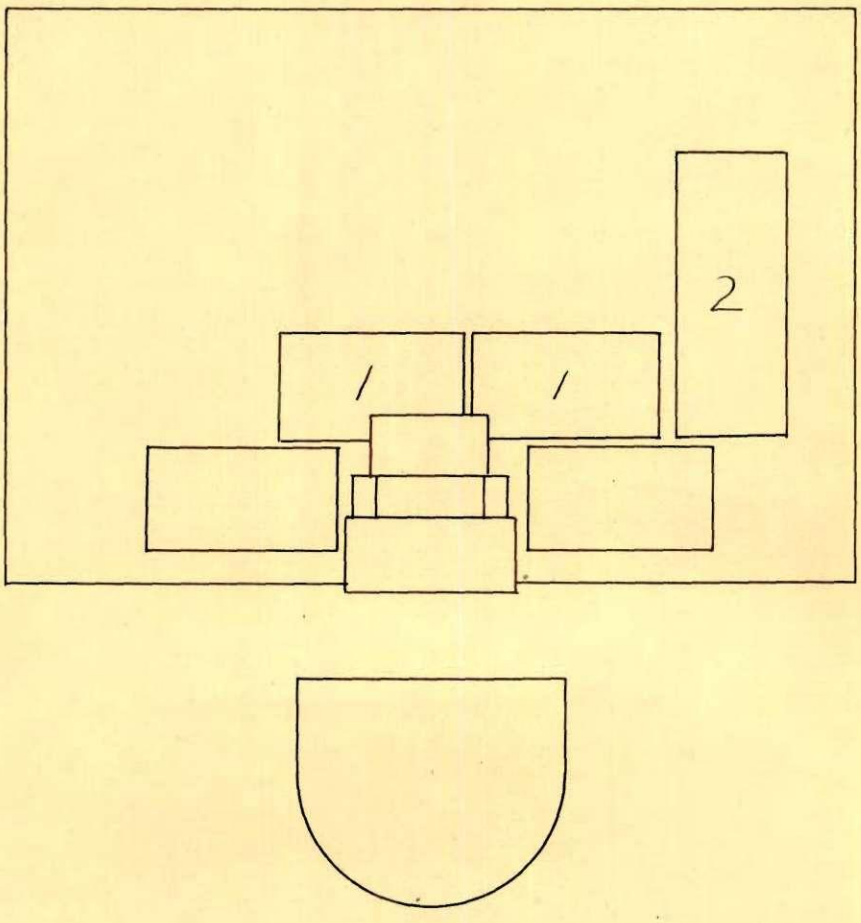
1. Barrels
2. Assembled Pens

Figure 9. - Layout 6 - Moveable Equipment



1. Barrels
2. Assembled Pens

Figure 10. - Layout 7 - Moveable Equipment



1. Barrels
2. Assembled Pens

Figure 11. - Layout 8 - Moveable Equipment

gives the completed unit to right-hand. Right-hand asides both assemblies. Operators using method: 14, 17 and 18.

Method No. 2 Left-hand and right-hand get barrels from ferrule tray. Left-hand gives completed unit to right-hand. Right-hand asides both assemblies. Operators using method: 1, 4, 6, 8, 9, 10, 11 and 12.

Method No. 3 Right-hand and left-hand get barrels in front. Right-hand and left-hand carry completed assemblies. Operators using method: 3 and 7.

Method No. 4 Right-hand and left-hand get barrels in front. Left-hand gives completed unit to right-hand. Right-hand carries completed assemblies. Operators using method: 2 and 5.

Method No. 5 Left-hand gets two barrels from the ferrule tray and gives one to right-hand. Left-hand gives completed assembly to right-hand. Right-hand asides completed assemblies. Operator using method: 13.

Method No. 6 Right-hand and left-hand get barrels in front. Left-hand gives to right-hand. Right-hand asides completed assemblies. Operators using method: 15 and 16.

Method No. 7 Right-hand and left-hand get barrels in front. Right-hand and left-hand aside completed assemblies in ferrule tray. Operator using method: 19.

Since the first and last elements of the cycles varied between different operations, it was necessary to separate that part of the cycle which contained these variations and the portion which did not. The overall cycle time was termed "gross cycle time" and the portion within the gross cycle not affected by variation in method was termed "modified cycle time."

Film Analysis Work Sheet.--A film analysis work sheet was filled out for each cycle in the operation (Fig. 12). The identification portion contained the operator's name, date of analysis, type of projector, name of analyist, cycle number, and film roll number. The body of the work sheet contained (1) element description, (2) therbligs involved, (3) frame number, (4) subtracted time and (5) remarks. The remarks consisted of notations on variation in method mentioned previously.

Selection of Variables.--On the basis of the notations on the film analysis sheets the variables were classified in the following categories:

1. Regrasp
2. Special combination of motions RL, TE, G, A, and RL
3. Delay one hand
4. Fumble
5. Drop part
6. Get two parts and return one
7. Inspect parts or delay both hands in the modified cycle
8.* Inspect parts or delay both hands after staking
9. Parts stuck in staker

* Variable number 8 applied to the gross cycle only. It was not included in the modified cycle time distributions.

Recording the Data.--Information from the film analysis work sheets was recorded on I.B.M. cards (No. 799619). Columns were provided for (1) shift number, (2) operator number, (3) shot for operator, (4) experience, (5) average production per hour, (6) gross cycle time, (7) modified cycle time, (8) gross layout and (9) gross method. The remainder of the card was used to record the occurrence of certain variables within the cycle previously mentioned.

Special notations were made on the card above the modified cycle time if (1) the normal method was abandoned, (2) the cycle included the aside of a handful of parts and (3) when the hands stopped to get a new supply of parts. Notations were made on the card above the gross cycle

Analysis Sheet for T-600 Ball Point Pen

Operator 1 Time 10:50 A Cycle 5 Film No. 10

Analyst GT Date of Analysis 6/22/53

Time Unit 1/2000

Description	Frame No. LH	Subtracted Time LH	Subtracted Time RH	Frame No. LH	Remarks
Get Blb-TE, ST&G	956 / 937			956 / 933	
Place Bbl-TL,P,A&RL	904			905	LH RG in A.
Get Unit-TE,S&G	881			893	
Place Unit-TL,P,A&RL	833			838	RH D in TL.
Get Dr. Nut-TE,ST&G	808			787	
Place Dr. Nut-TL,P,A&RL	740			747	LH 2 TURN RH 1 TURN.
Get Ferrule-TE,ST,&G	727			731	LH DROP PART IN TL
Place Ferrule-TL,P,A&RL	710			708	
Get Comp. Unit-TE&G	704			704	
Place Comp. Unit-DA,TL&P	688			661	
Stake-A,H&D.A.	630			634	
Aside-TL	613			603	LH GIVES TO RH RH ASIDES

Gross Cycle Time 353

Modified Time 307

Figure 12. Film Analysis Form

time when there was no aside of completed assemblies. Cycles containing these notations were eliminated for the distributions.

Sorting the Cards.--An I.B.M. sorting machine equipped with pocket counters were used to sort the cards and secure distribution data. The data were recorded on a distribution record form (Fig. 13) provided for this purpose.

The Gross Cycle Distribution.--A gross cycle time distribution with all variables included was obtained for all shifts combined. Since the gross cycle time includes the modified cycle, only cycles meeting the modified cycle criteria were used. Cycles containing major deviations in methods in the gross cycle were sorted out as previously mentioned. Approximately ten per cent of the cycles were eliminated for this reason.

Modified Cycle Time Distributions.--Cycles containing major deviations in methods not classified as variables in the modified cycles were sorted out as mentioned previously. Approximately twenty-two per cent of the total cycles were eliminated for this reason. These cycles were not used in any of the distributions. Modified cycle time distributions with all variables included were obtained for (1) each operator individually, (2) each shift and (3) total of all shifts combined. The cycles containing variables were then sorted out, and modified cycle time distributions were obtained for (1) each shift and (2) total all shifts combined.

Examination of Distributions.--The distributions for the modified cycle times were examined visually; all the distributions exhibited a positive skewness.

As an additional check on the total three-shift distributions, the data were plotted on probability paper using a log scale for the

Shift /

Operator /

Variables Included ALL

Tens

Hundreds	0	1	2	3	4	5	6	7	8	9	Total
0											
1											
2		2	2	0	2	5	3	6	3	4	27
3	3	10	7	2	0	2	2	0	1	0	27
4	1										1
5											
6											
7											
8											
9											

Figure 13. Distribution Record Form

cycle times. These plots appeared to give a satisfactory straight line relationship.

A gross cycle time distribution with all variables included was also prepared. This distribution was positively skewed.

CHAPTER V

RESULTS

Modified Cycle Time Distributions

The following characteristics were observed from a visual examination of the modified cycle time histograms (Figures 14-40).

Variables Included.--Modified cycle time distributions for the individual operators with all variables included tend to be positively skewed. Histograms for operators 5 and 6 (Figures 18 and 19) indicated a lack of good cycles in the sample. Shift distributions of modified cycle times with all variables included are positively skewed. This was also true of distribution of all shifts combined (Fig. 36).

Variables Excluded.--Shift modified cycle time distributions were positively skewed (Figures 37, 38 and 39). The sample size in the first shift was considerably smaller than the other two shifts. This indicated that a greater number of variables were present among the cycles performed. Positive skewness was also exhibited in the distribution of all three shifts combined (Fig. 40).

Gross Cycle Time Distribution

The gross cycle time distribution of all shifts combined was positively skewed (Fig. 41).

Effect of Variables on the Cycle Time Distribution

There was considerable change in the general characteristics of the modified cycle time distribution when the variables were removed

(Fig. 42). Height of the distribution was decreased because the sample size was reduced. Peakedness was noticeably decreased, and the slope of the tales was reduced.

A plot of the distributions on probability paper using a log scale for the cycle time (Figures 43 and 44) indicated that the modified cycle time distributions of all shifts, with variables included and variables excluded, approximated a straight line relationship.

Table 1. First Shift - Modified Cycle Time Distribution - No Variables Eliminated

Modified Cycle Time in Frames	Op. No. 1	Op. No. 2	Op. No. 3	Op. No. 4	Op. No. 5	Op. No. 6	Op. No. 7	Total Operators 1-7
150-159		1						1
160-169		0						0
170-179		1	1					2
180-189		1	0		1			2
190-199		2	0		1		1	4
200-209		2	0	2	2		2	8
210-219	2	5	1	3	1		2	14
220-229	2	2	0	2	1		5	12
230-239	0	6	3	3	2		3	17
240-249	2	4	6	4	5		3	24
250-259	5	12	5	4	1		4	31
260-269	3	5	5	6	3		10	32
270-279	6	5	8	5	4		6	34
280-289	3	9	10	3	4		6	35
290-299	4	2	1	1	3		3	14
300-309	3	4	5	2	1		5	20
310-319	10	4	1	3	1		3	22
320-329	7	2	0	1	2		6	18
330-339	2	1	4	2	0		1	10
340-349	0	3	1	0	1		2	7
350-359	2	1	2	1	3		2	11
360-369	2	0	0	1	1			4
370-379	0	2	0	0	1			3
380-389	1	0	0		0			1
390-399	0	2	1		0			3
400-409	1	0			0			1
410-419		1			0			1
420-429					1			1
430-439					0			0
440-449					0			0
450-459					0			0
460-469					0			0
470-479					2			2

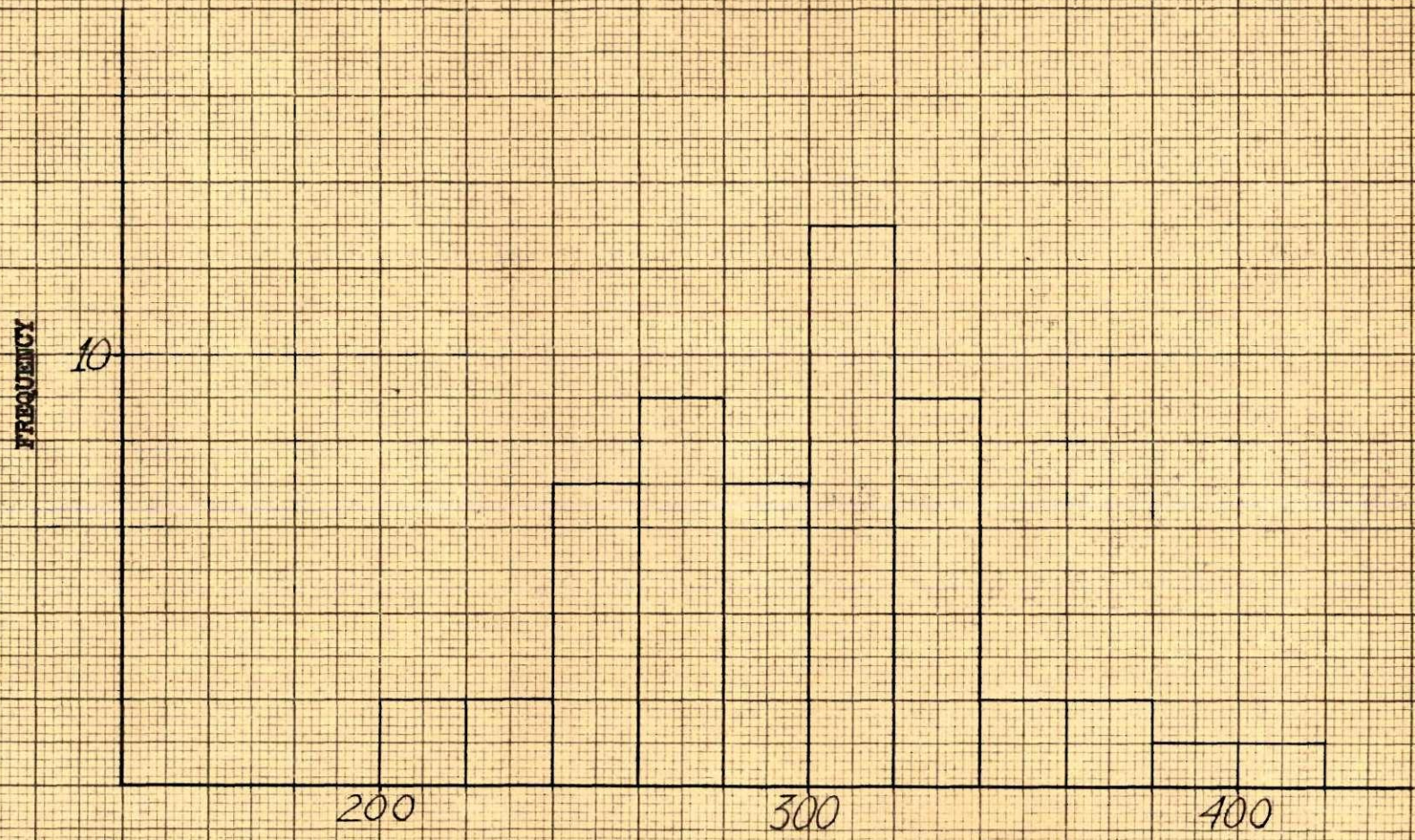


Figure 14. Operator 1 - Modified Cycle Time Histogram - No Variables Eliminated

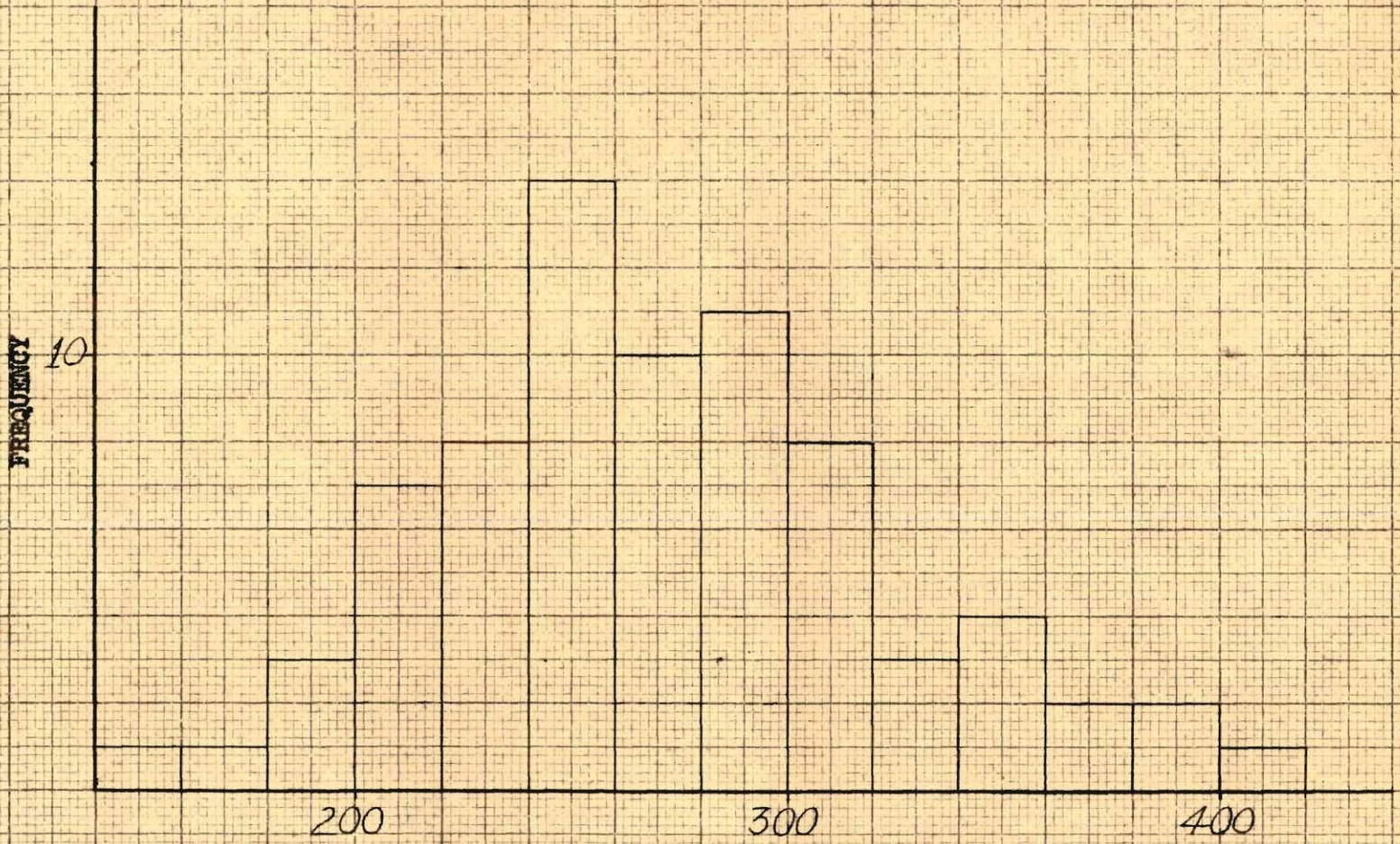


Figure 15. Operator 2 - Modified Cycle Time Histogram - No Variables Eliminated

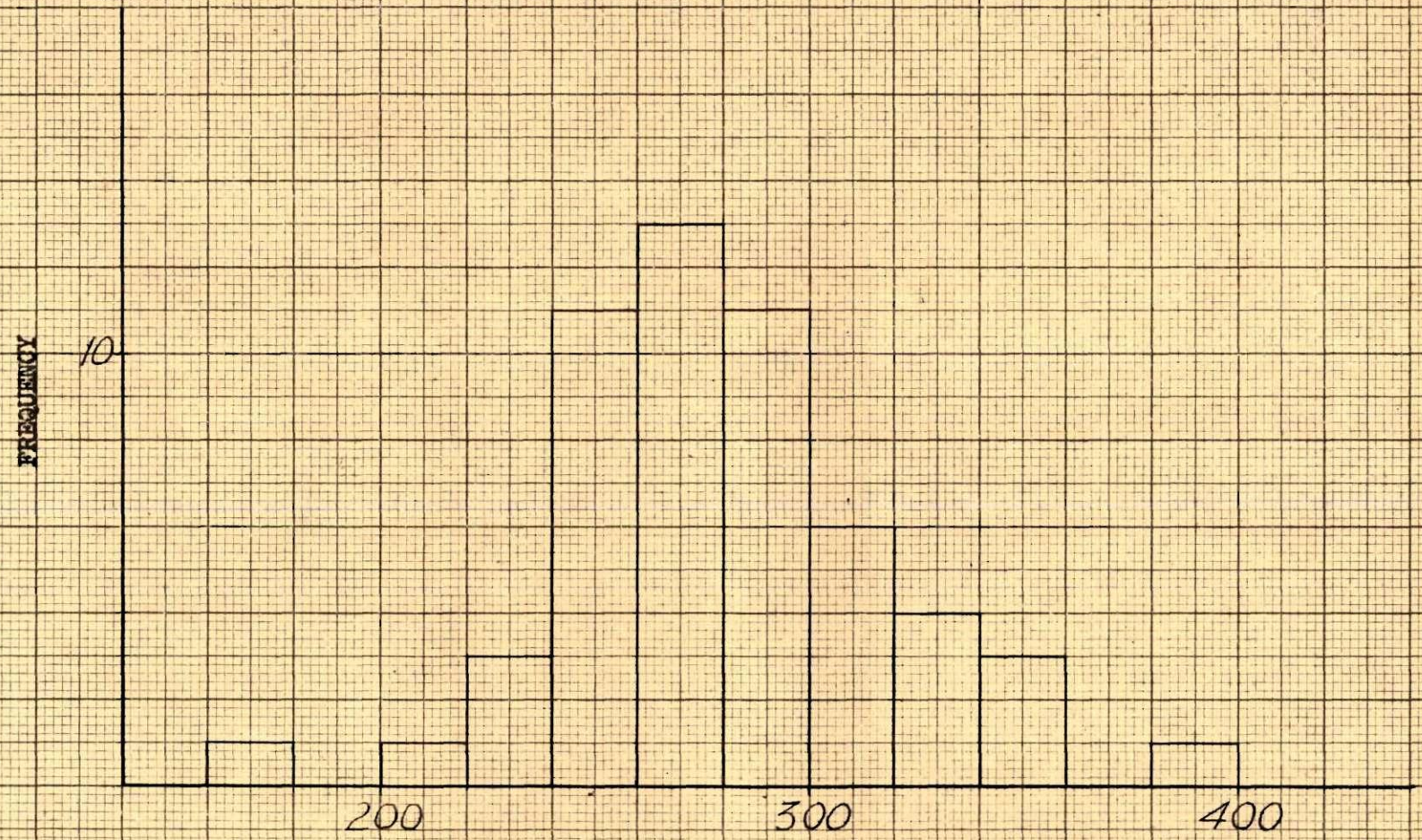


Figure 16. Operator 3 - Modified Cycle Time Histogram - No Variables Eliminated

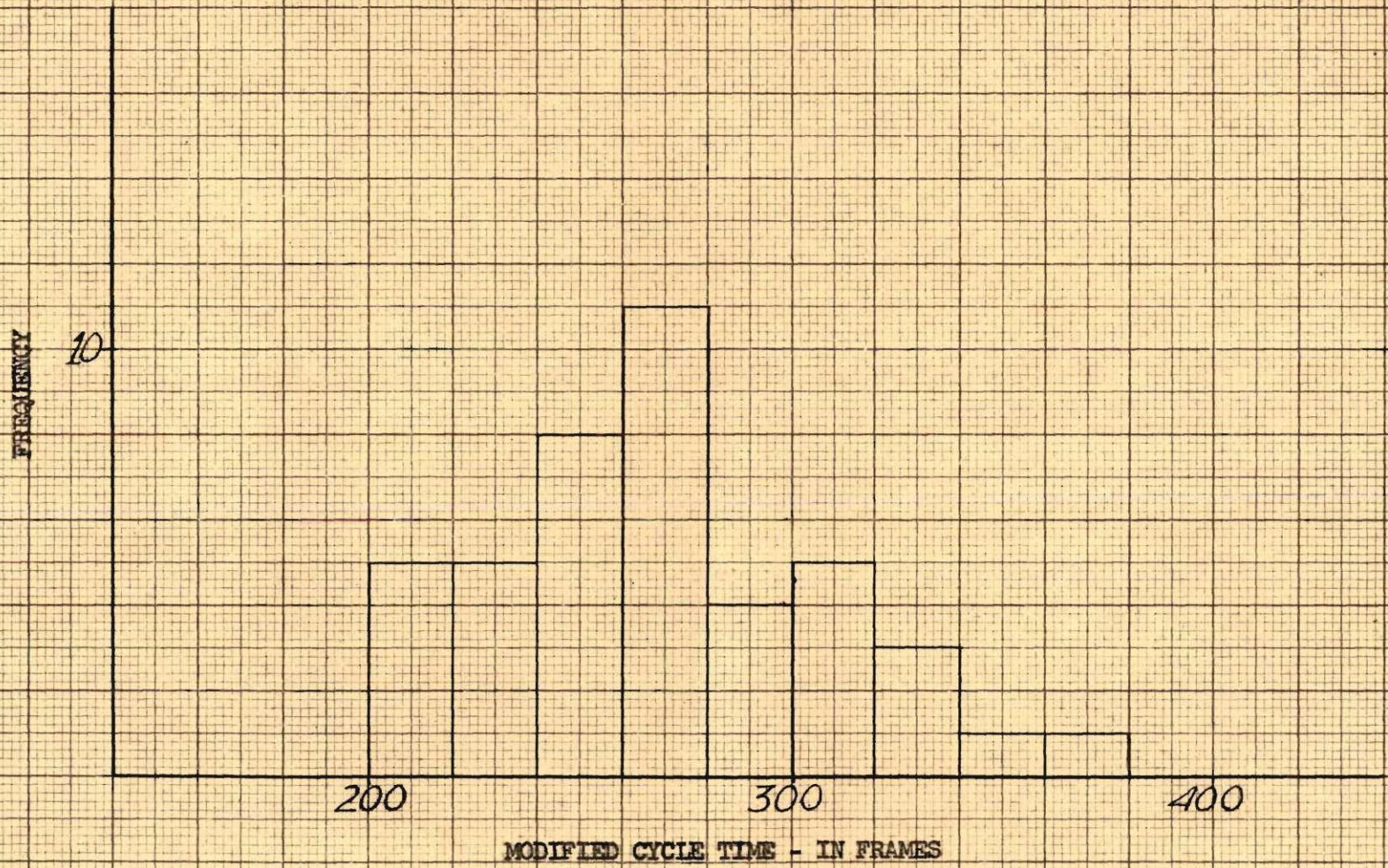


Figure 17. Operator 4 - Modified Cycle Time Histogram - No Variables Eliminated

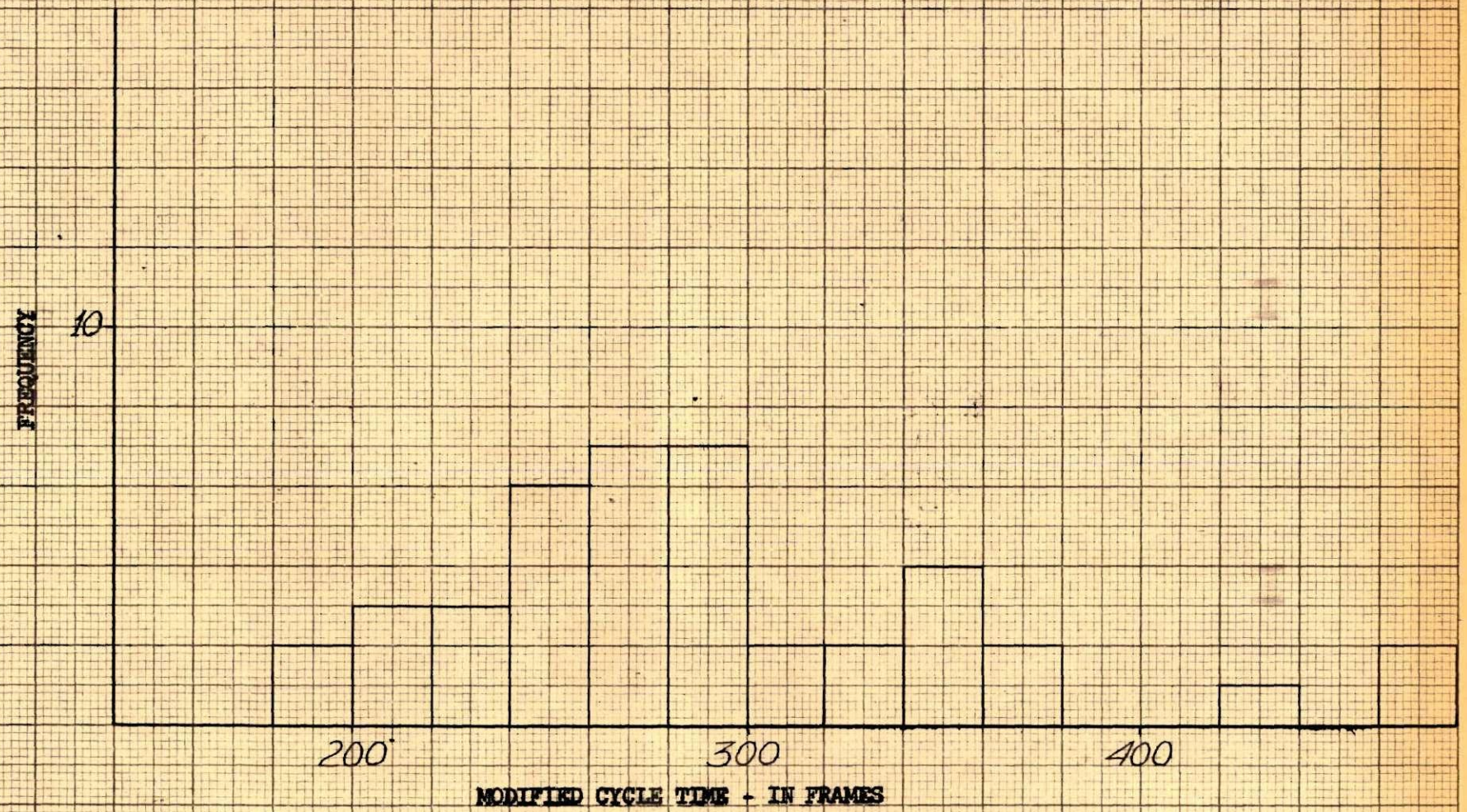


Figure 18. Operator 5 - Modified Cycle Time Histogram - No Variables Eliminated

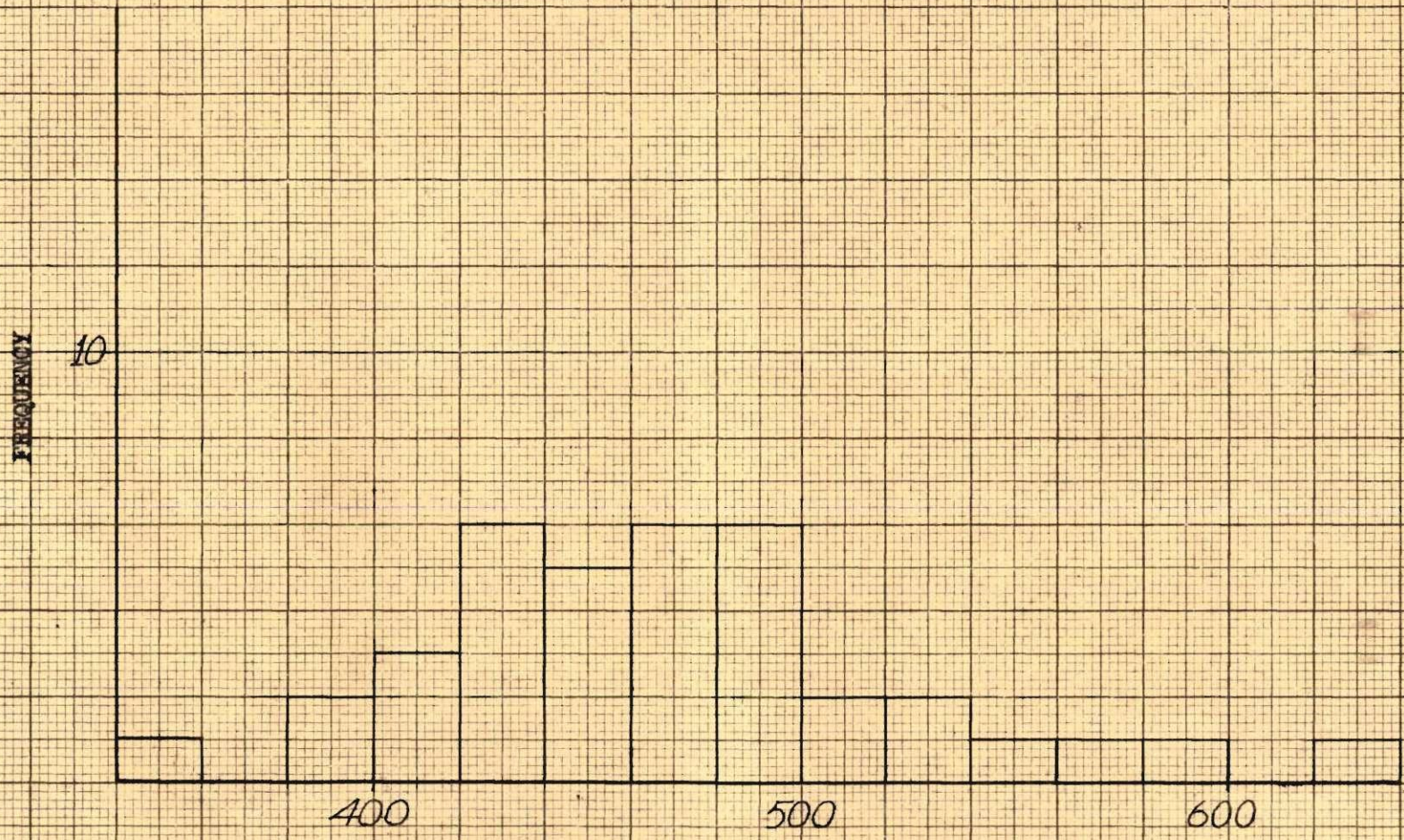


Figure 19. Operator 6 - Modified Cycle Time Histogram - No Variables Eliminated

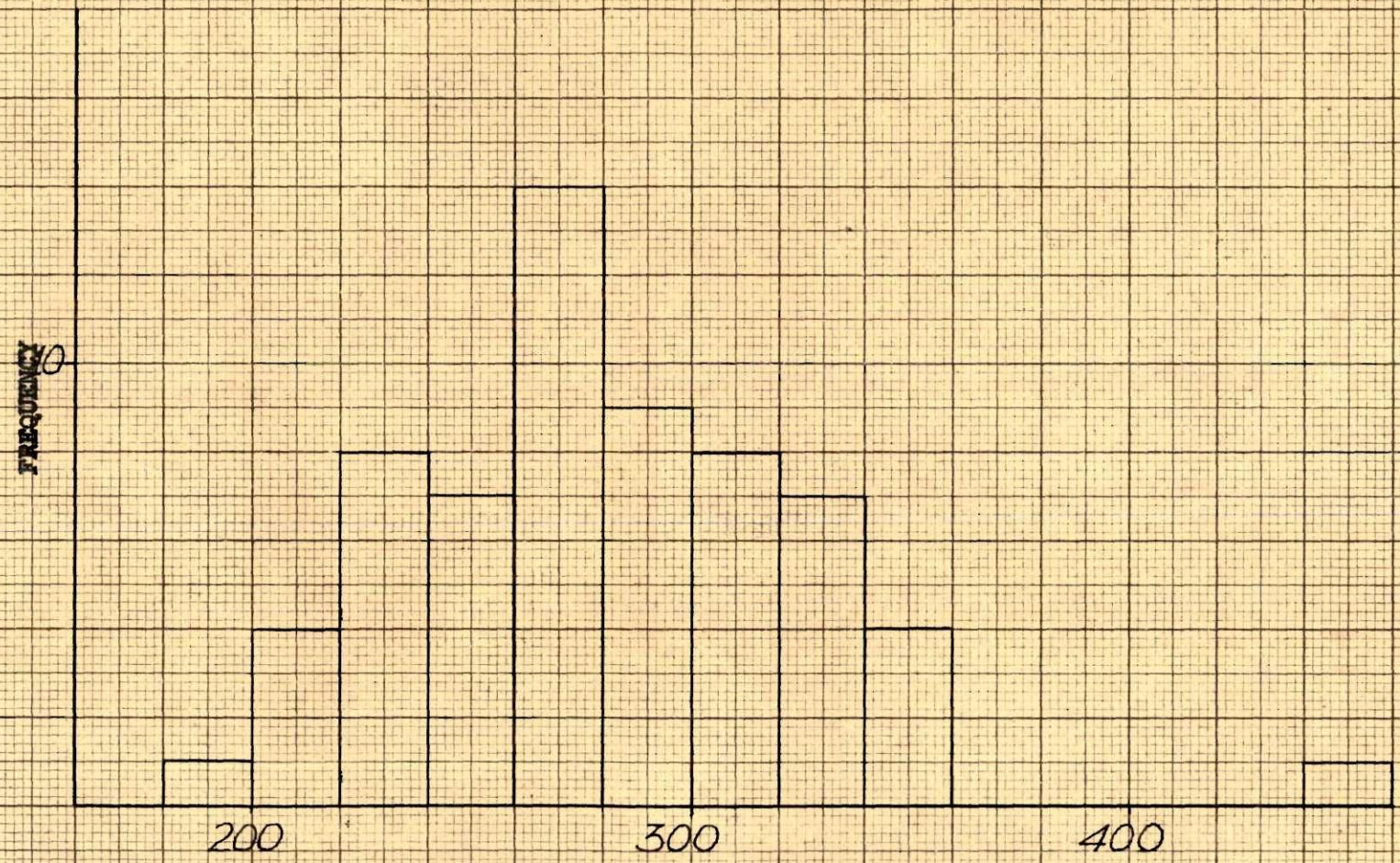


Figure 20. Operator 7 - Modified Cycle Time Histogram - No Variables Eliminated

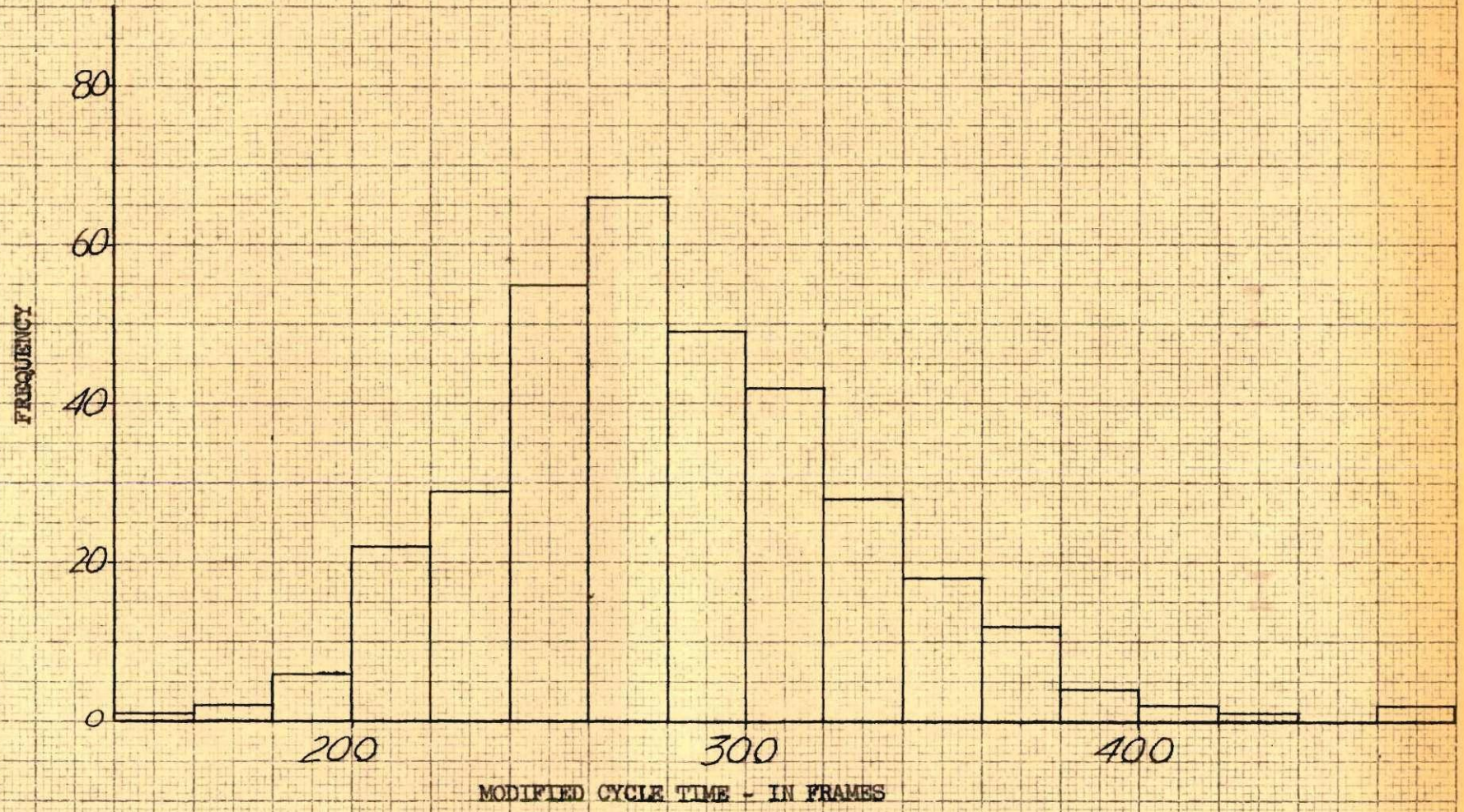


Figure 21. Operators 1-7 - First Shift - Modified Cycle Time Histogram - No Variables Eliminated

Table 2. Second Shift - Modified Cycle Time Distribution - No Variables Eliminated

Modified Cycle Time in Frames	Op. No. 8	Op. No. 9	Op. No. 10	Op. No. 11	Op. No. 12	Op. No. 13	Total Operators 8-13
150-159							
160-169			1				1
170-179			0				0
180-189		1	0				1
190-199		0	0				0
200-209		0	0		1		1
210-219		1	0	1	1	2	5
220-229		4	0	2	0	3	9
230-239		6	1	3	0	8	18
240-249	3	17	2	10	0	13	45
250-259	1	9	3	12	0	14	39
260-269	4	9	5	8	1	13	40
270-279	3	8	10	5	1	10	37
280-289	11	5	9	12	0	5	42
290-299	9	4	3	6	1	5	28
300-309	10	3	8	3	6	3	33
310-319	3	5	5	5	5	1	24
320-329	4	1	6	0	8	1	20
330-339	6	3	3	1	9	3	25
340-349	3	0	6	2	7	0	18
350-359	1	2	0	3	4	1	11
360-369	1	0	2	0	5	0	8
370-379	1	0	1	0	7	0	9
380-389	1	0	1	0	2	0	4
390-399	1	0	1	1	2	0	5
400-409	2	1	2	1	1	0	7
410-419	2		0	0	1	0	3
420-429	1		0	2	0	0	3
430-439			1		0	1	2
440-449					1		1

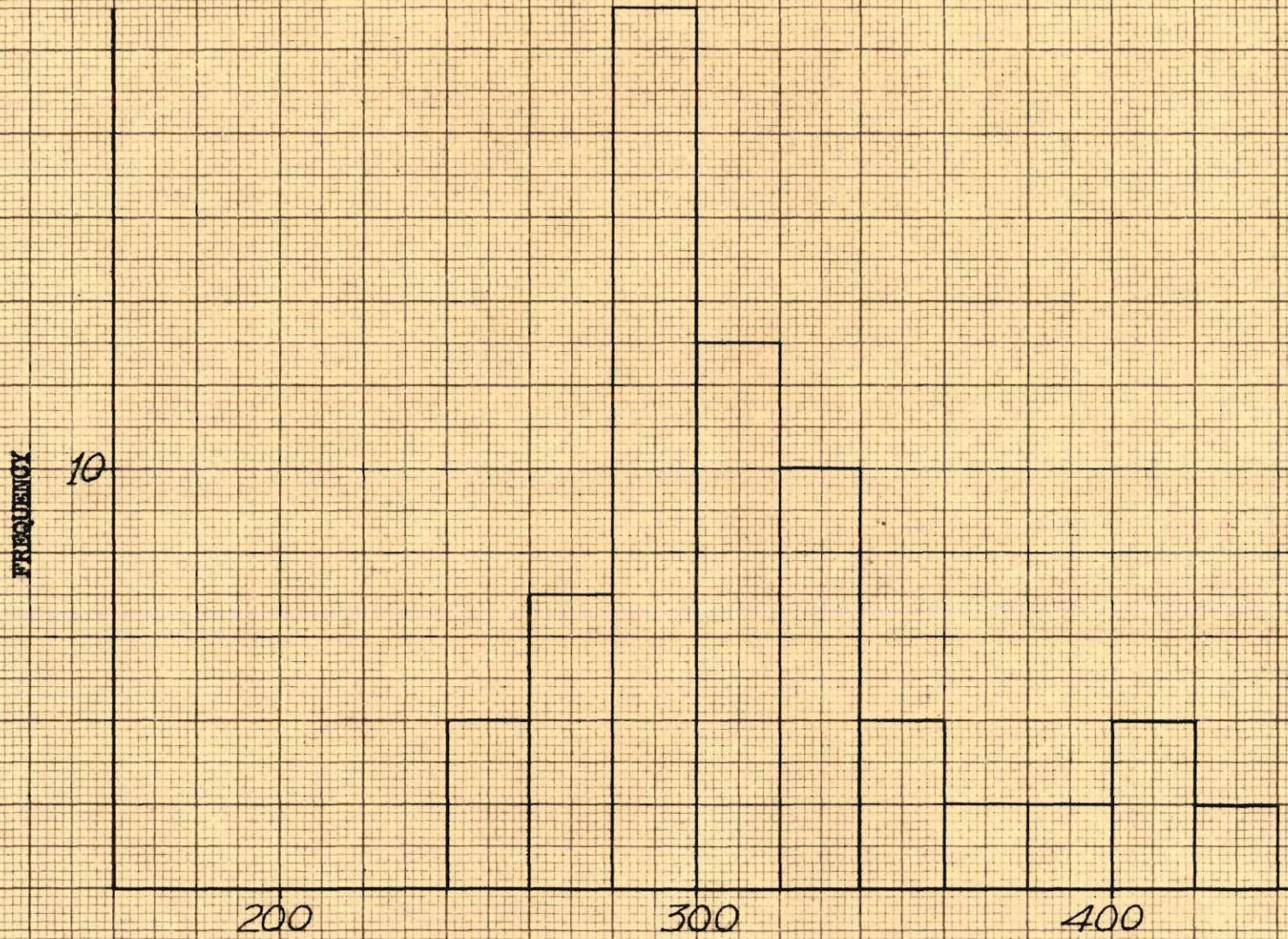


Figure 22. Operator 8 - Modified Cycle Time Histogram - No Variables Eliminated

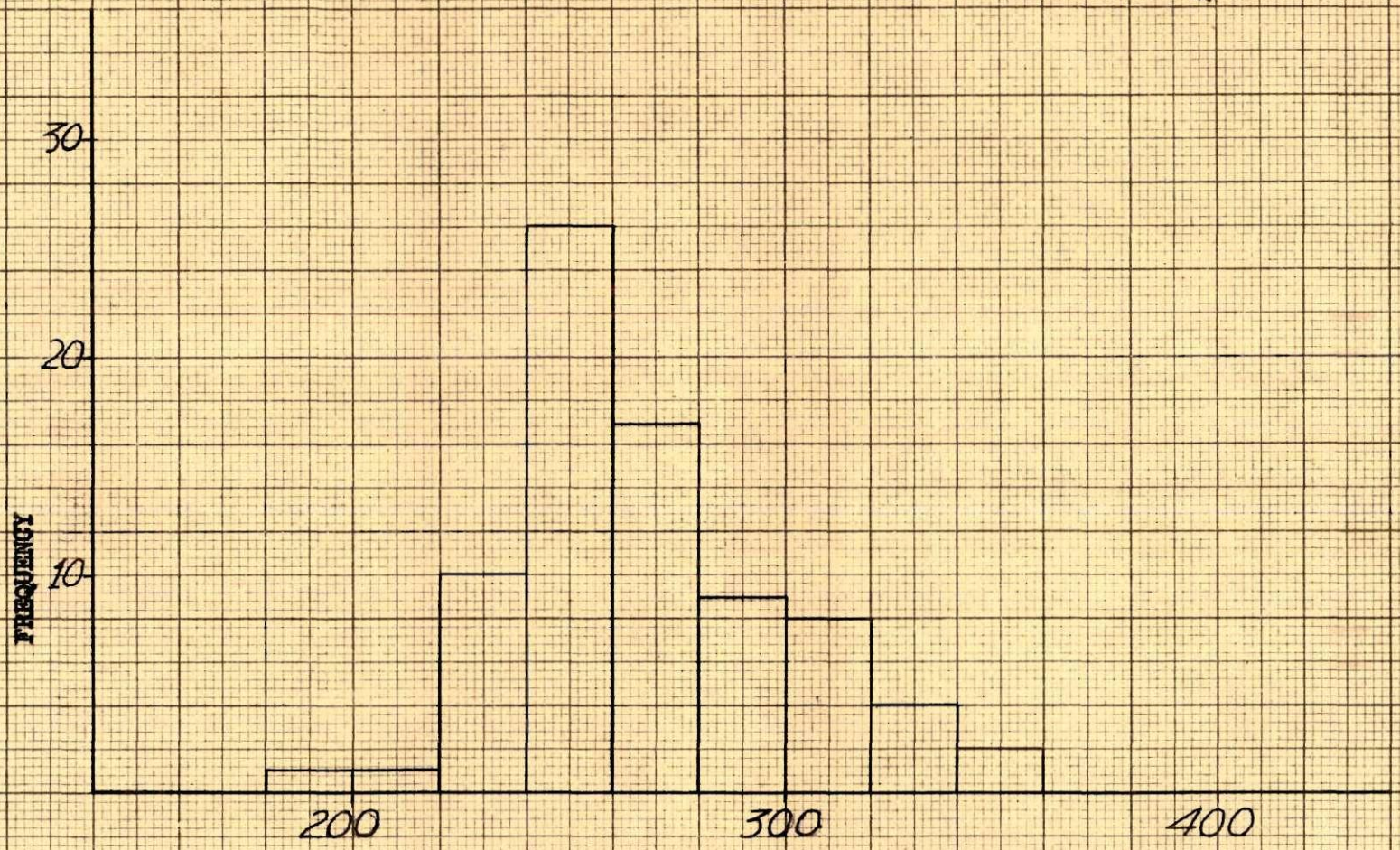


Figure 23. Operator 9 - Modified Cycle Time Histogram - No Variables Eliminated

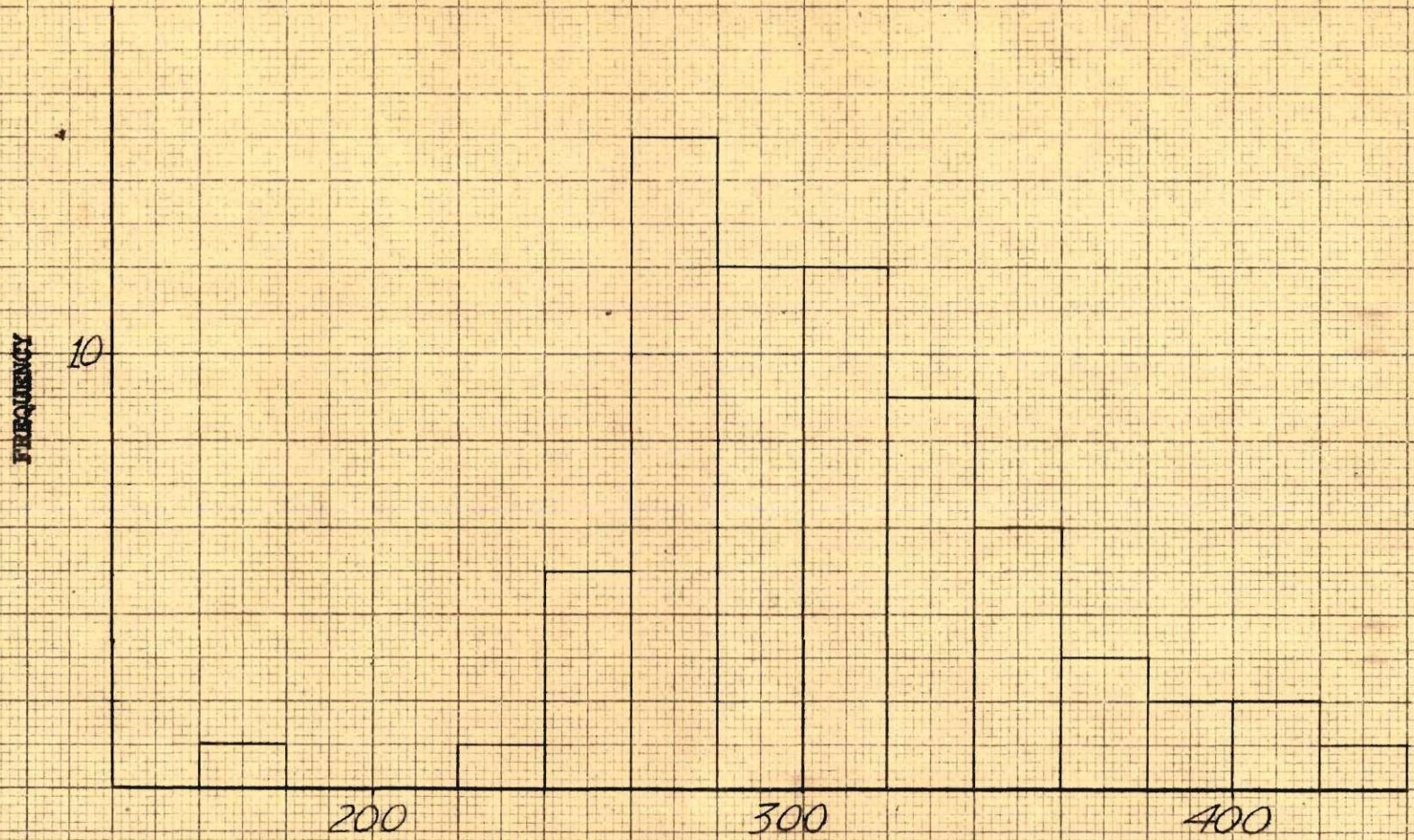


Figure 24. Operator 10 - Modified Cycle Time Histogram - No Variables Eliminated

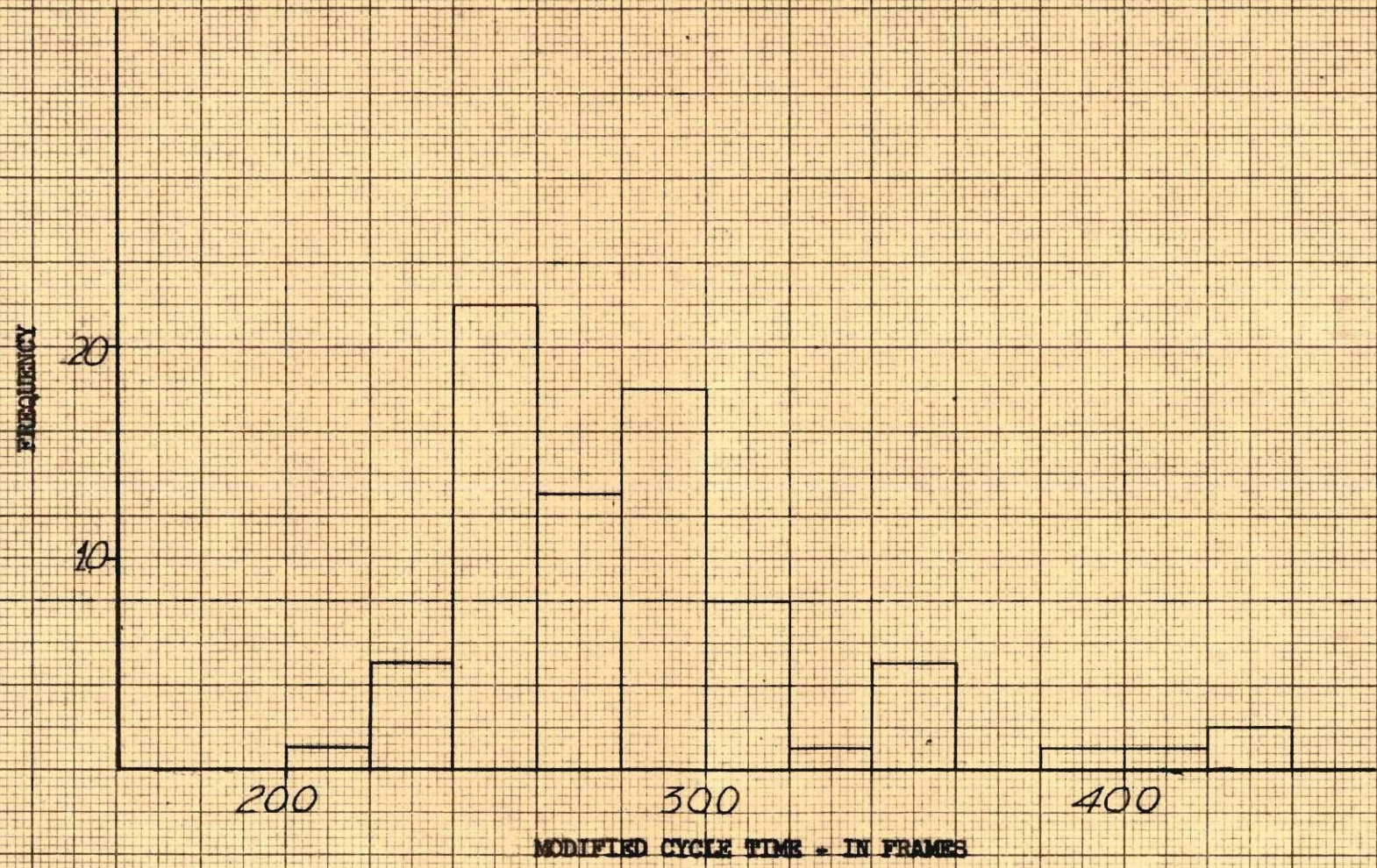


Figure 25. Operator 11 - Modified Cycle Time Histogram - No Variables Eliminated

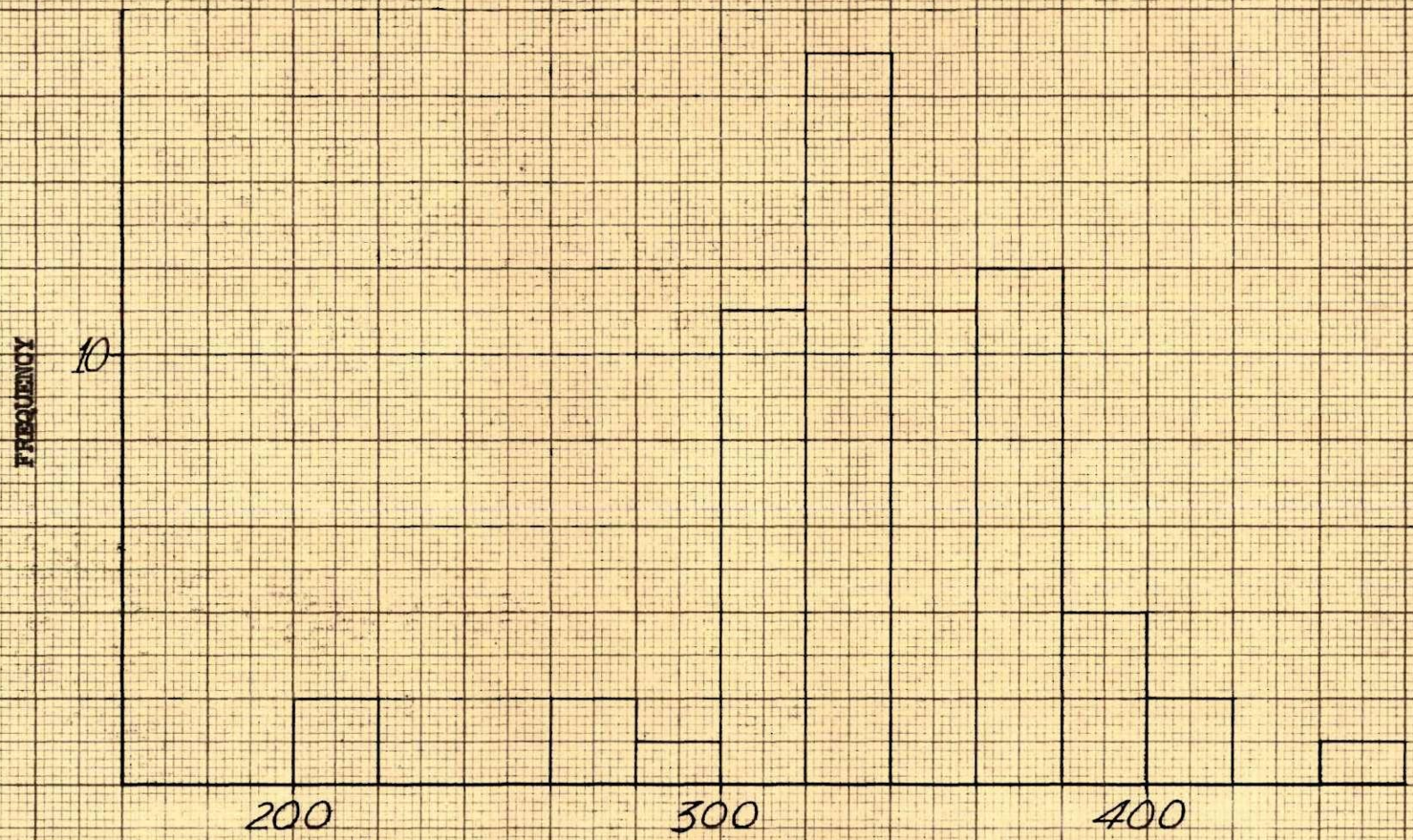


Figure 26. Operator 12 - Modified Cycle Time Histogram - No Variables Eliminated

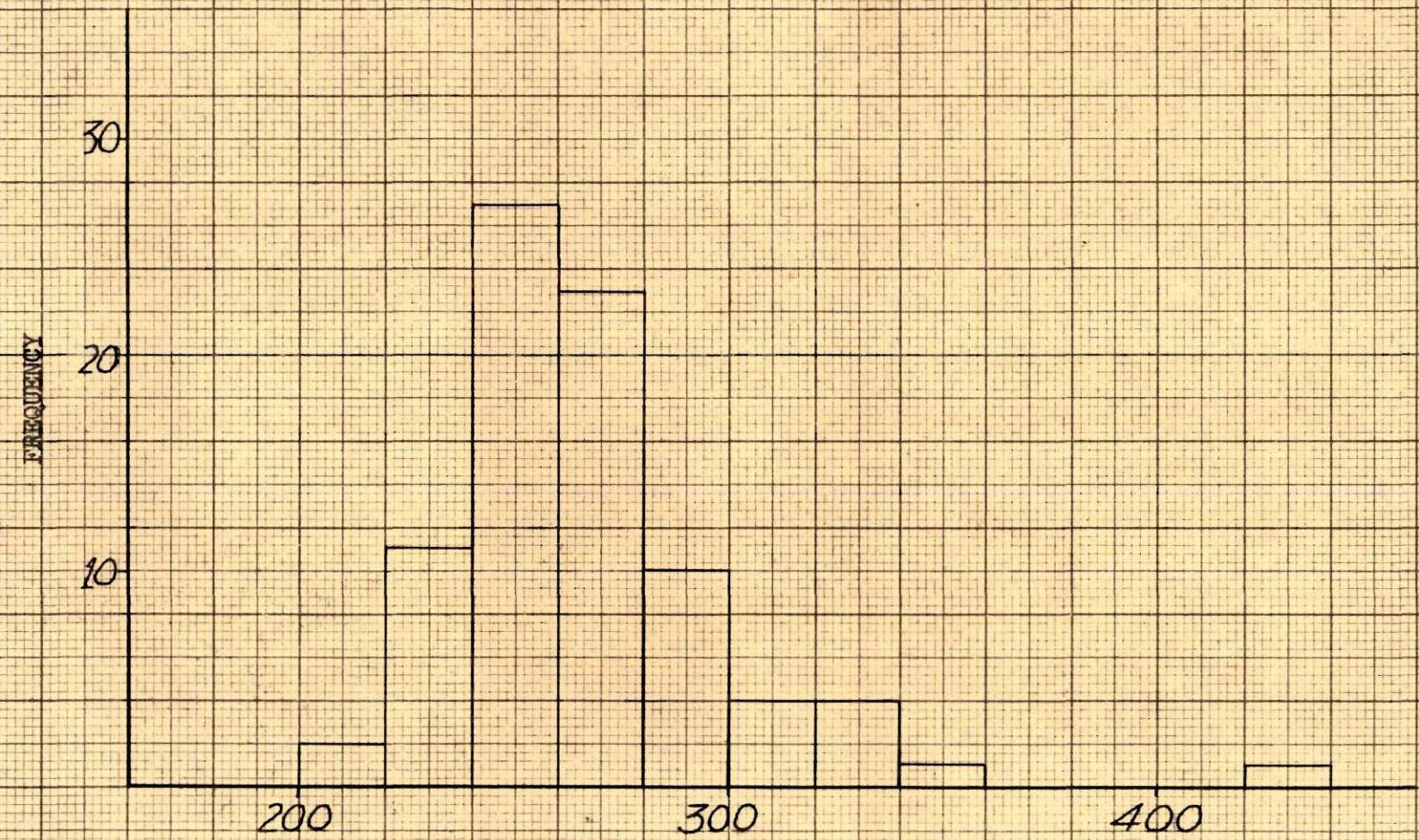


Figure 27. Operator 13 - Modified Cycle Time Histogram - No Variables Eliminated

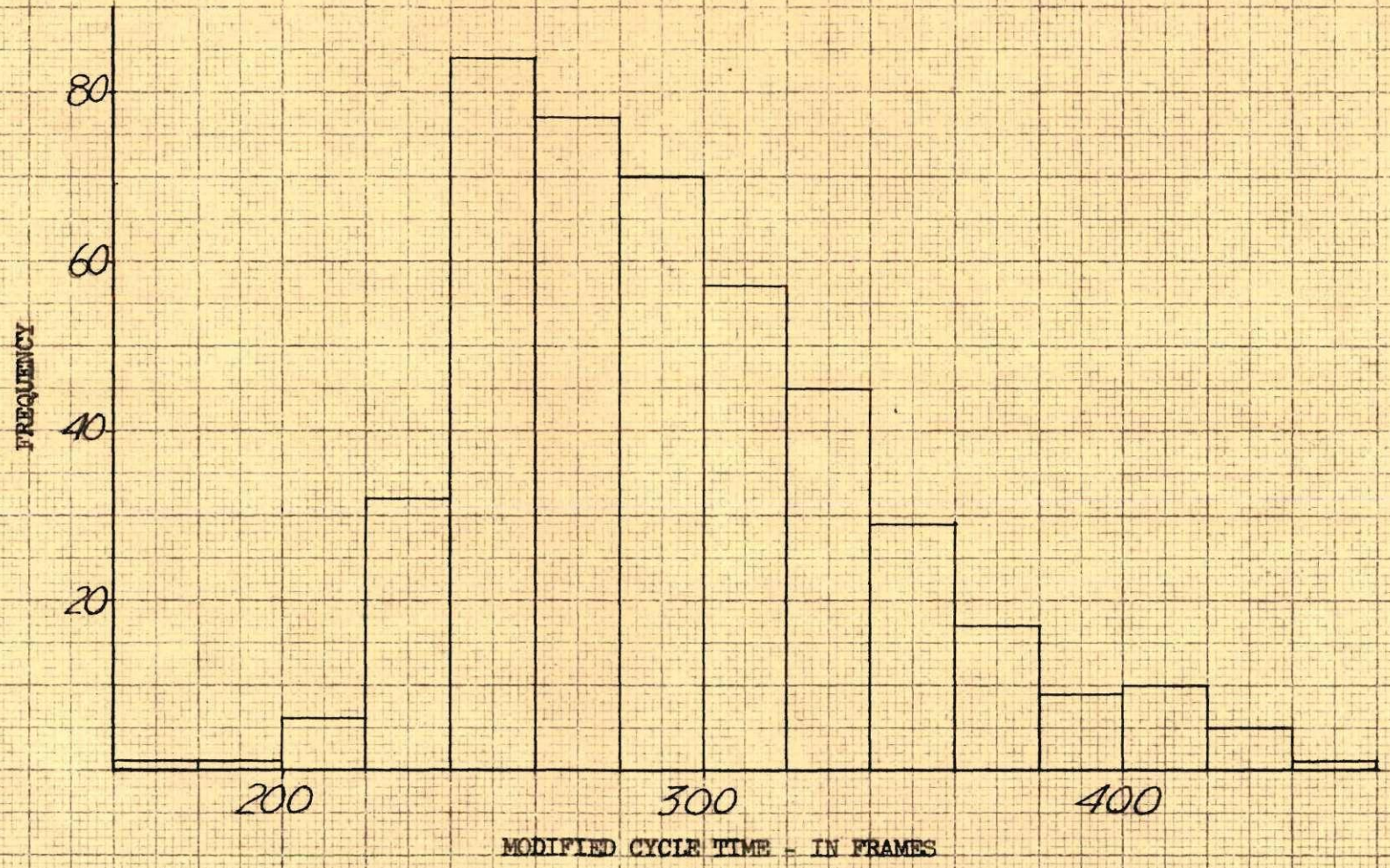


Figure 28. Operators 8-13 - Second Shift - Modified Cycle Time Histogram - No Variables Eliminated

Table 3. Third Shift - Modified Cycle Time Distribution - No Variables Eliminated

Modified Cycle Time in Frames	Op. No. 14	Op. No. 15	Op. No. 16	Op. No. 17	Op. No. 18	Op. No. 19	Total Operators 14-19
200-209							
210-219			1	5			6
220-229			1	7			8
230-239			3	12	8		23
240-249			9	16	13	1	39
250-259		1	6	14	23	1	45
260-269		2	8	13	16	1	40
270-279		11	9	9	8	1	38
280-289	1	10	9	4	6	7	37
290-299	1	7	8	2	8	8	34
300-309	4	9	5	2	2	4	26
310-319	4	13	3	1	3	6	30
320-329	10	1	3	1	3	9	27
330-339	2	10	3	2	0	11	28
340-349	4	2	1		0	2	9
350-359	3	3	3		0	4	13
360-369	2	5	3		1	3	14
370-379	5	2	0			0	7
380-389	1	3	0			2	6
390-399	2	0	0			3	5
400-409	0	0	1			1	2
410-419	1	1				1	3
420-429	0					0	0
430-439	1					0	1
440-449	0					1	1
450-459	0					1	1
460-469	1						1
470-479	1						1

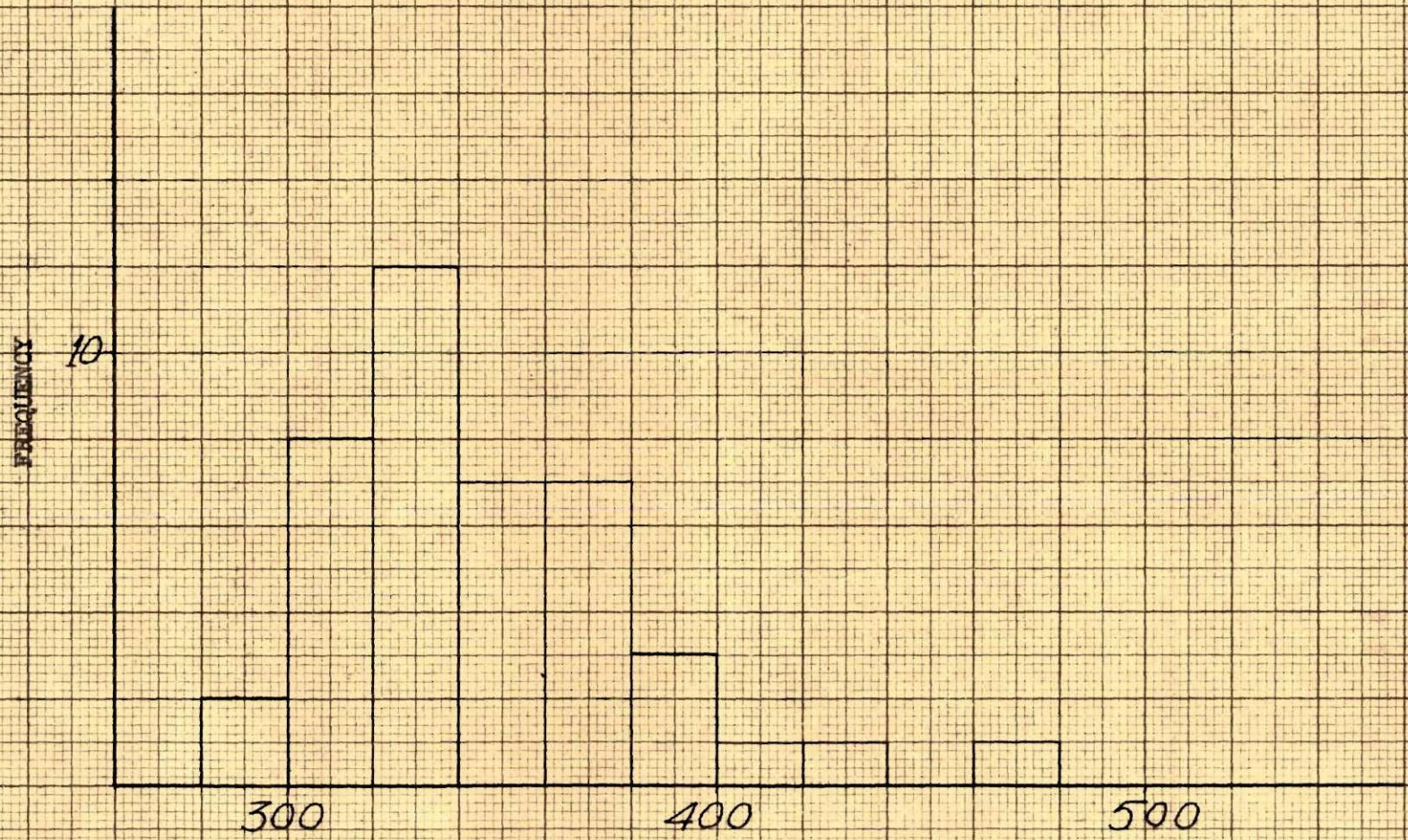


Figure 29. Operator 14 - Modified Cycle Time Histogram - No Variables Eliminated

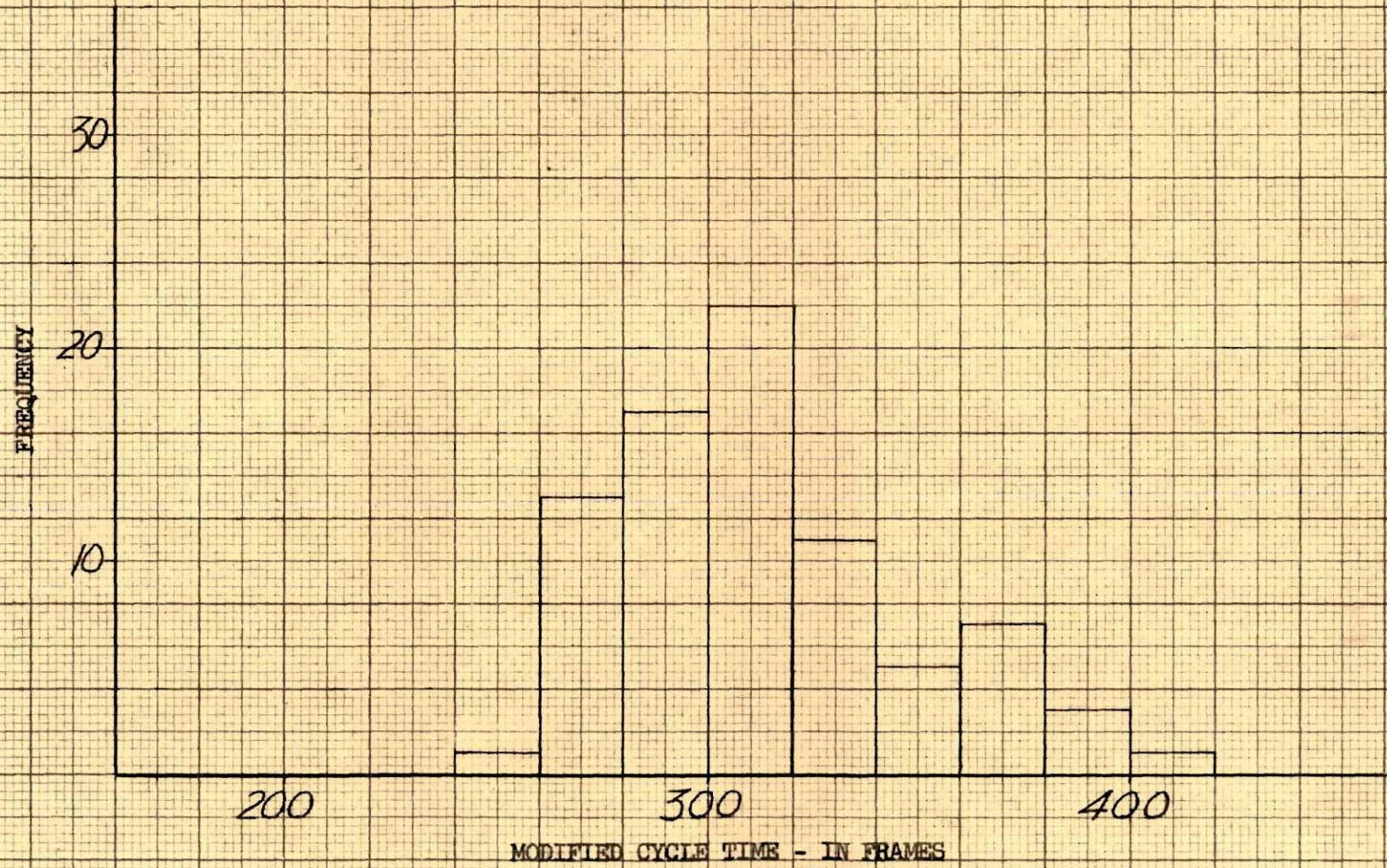


Figure 30. Operator 15 - Modified Cycle Time Histogram - No Variables Eliminated

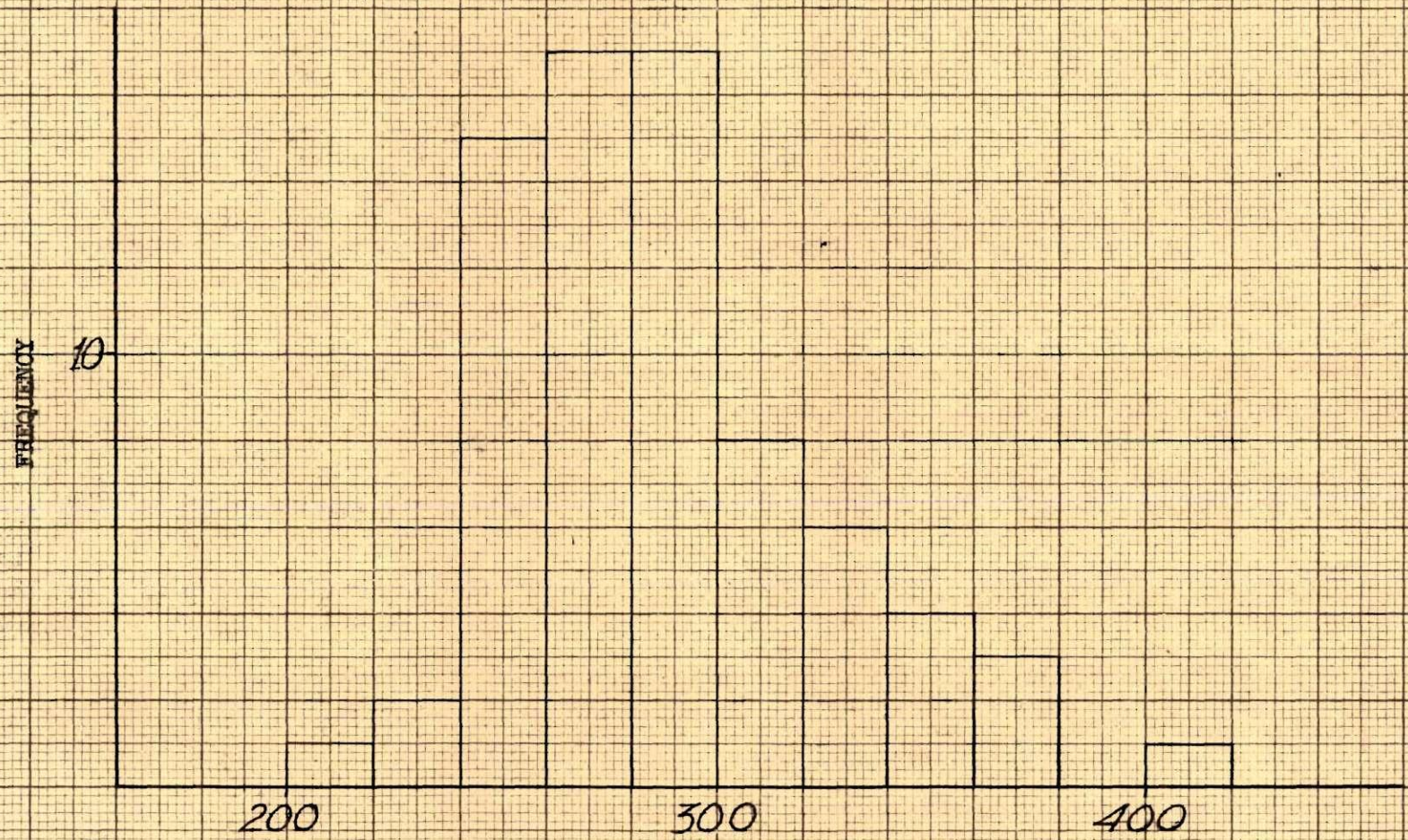


Figure 31. Operator 16 - Modified Cycle Time Histogram - No Variables Eliminated

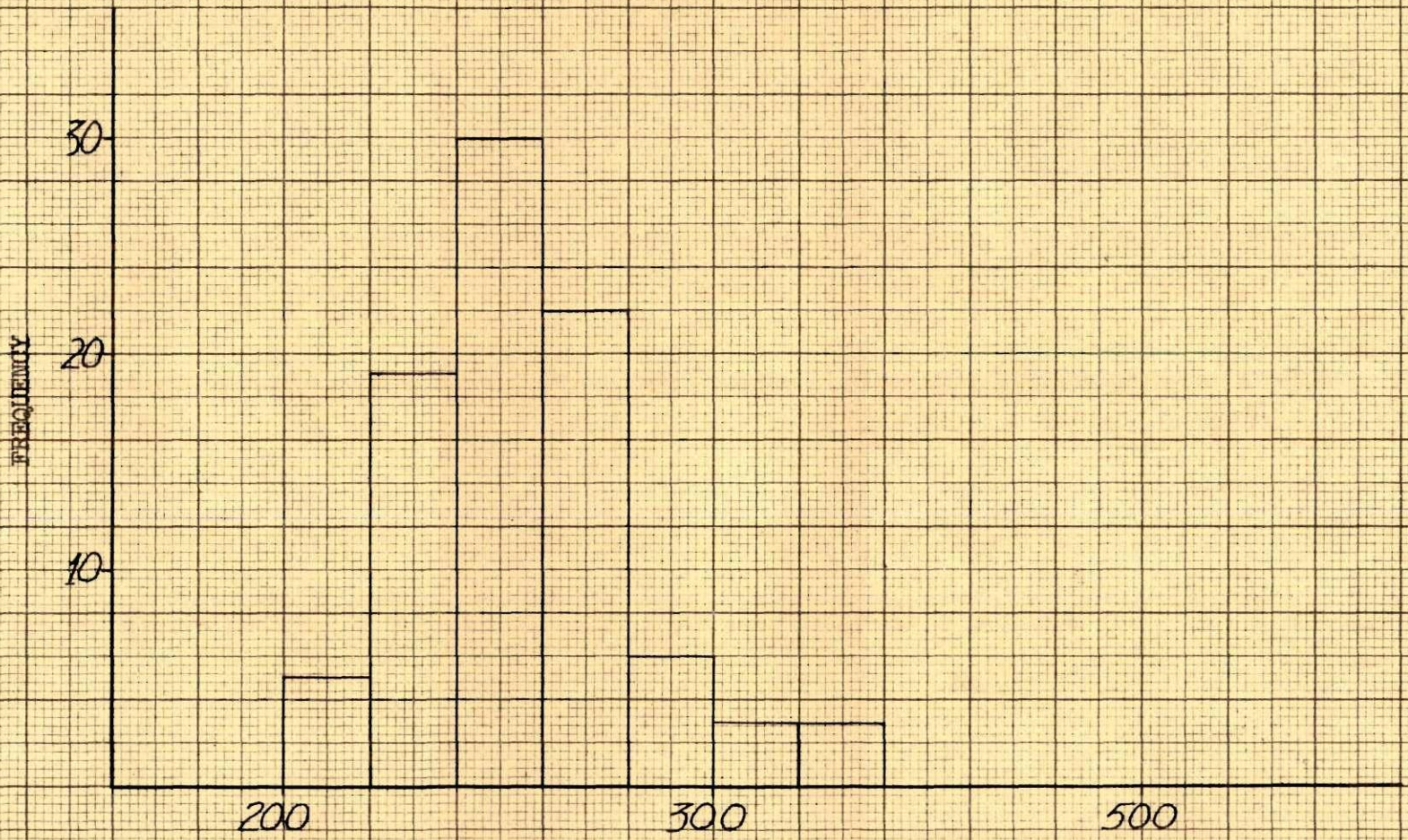


Figure 32. Operator 17 - Modified Cycle Time Histogram - No Variables Eliminated

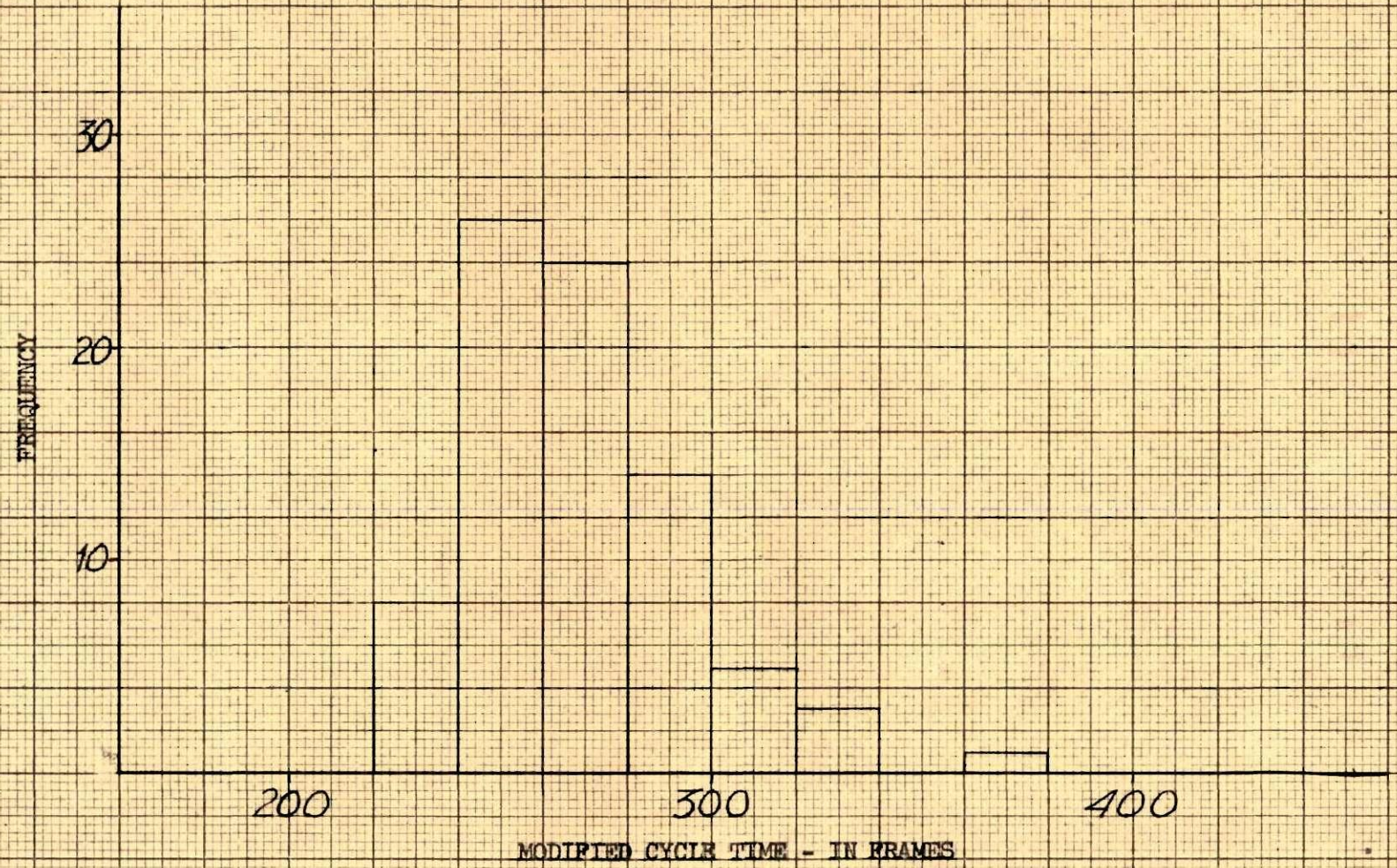


Figure 33. Operator 18 - Modified Cycle Time Histogram - No Variables Eliminated

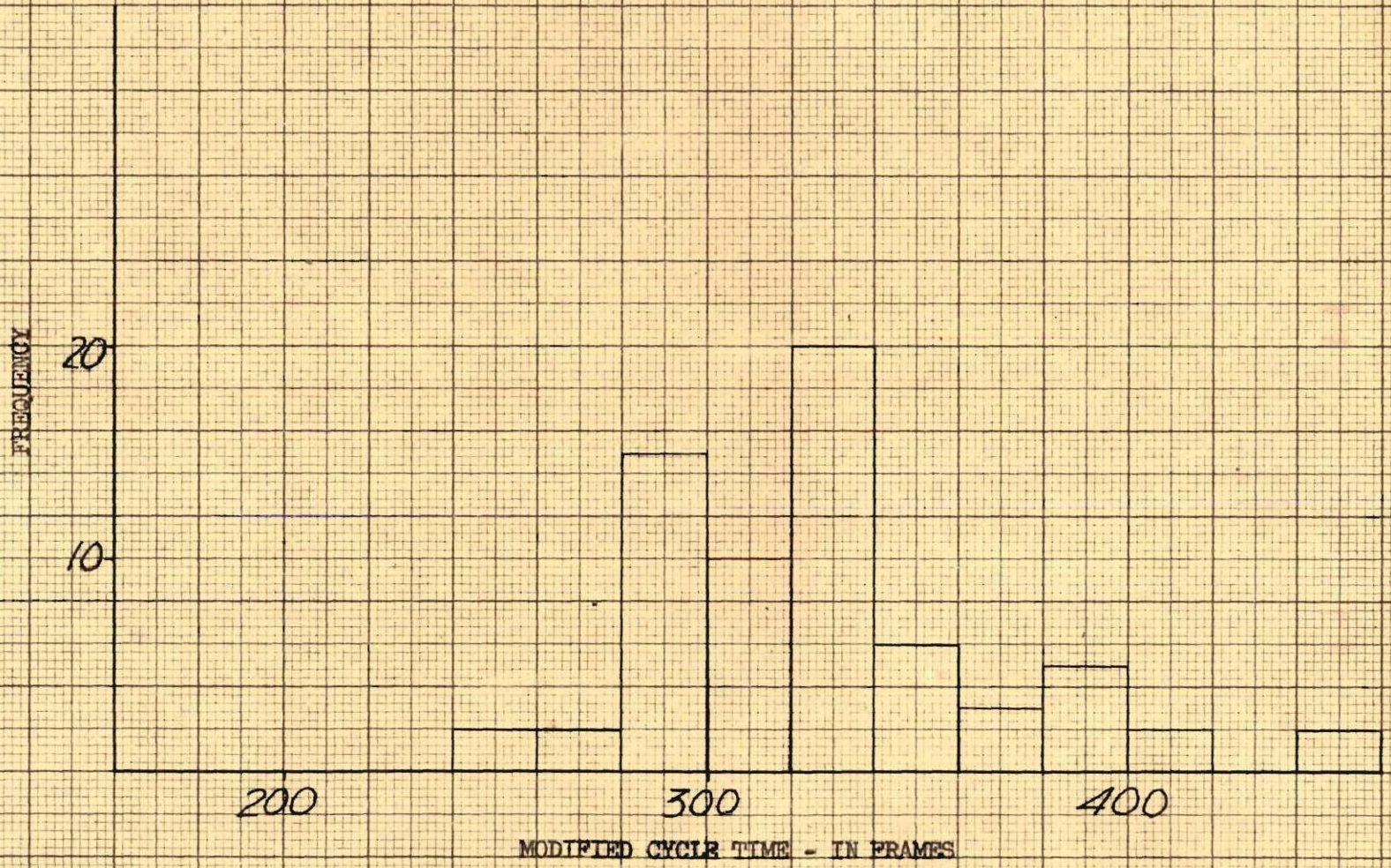


Figure 34. Operator 19 - Modified Cycle Time Histogram - No Variables Eliminated

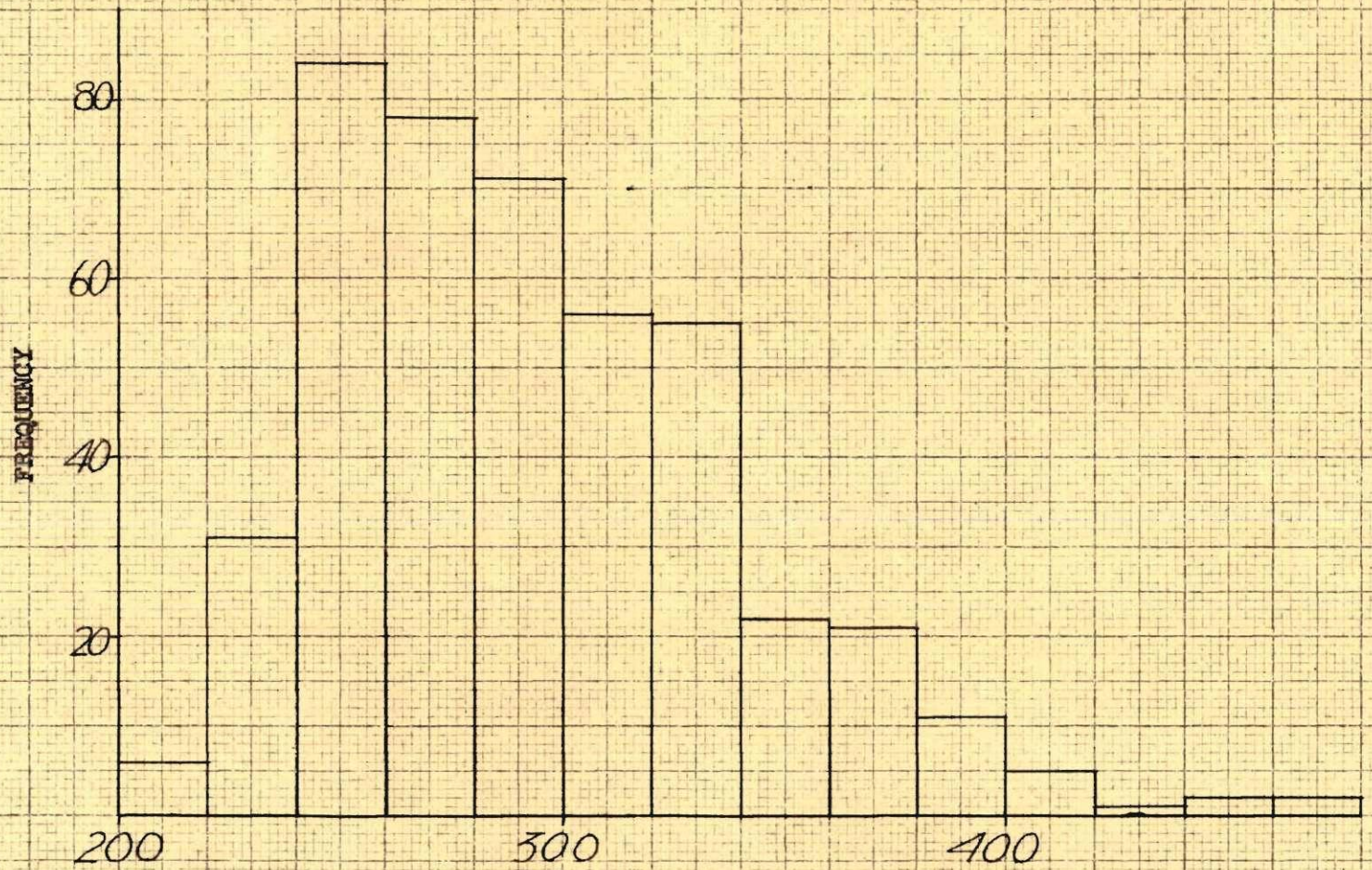


Figure 35. Operators 14-19 - Third Shift - Modified Cycle Time Histogram - No Variables Eliminated

Table 4. All Shifts - Modified Cycle Time Distribution - No Variables Eliminated

Modified Cycle Time in Frames	Shift No. 1	Shift No. 2	Shift No. 3	Total All Shifts
150-159	1			1
160-169	0			1
170-179	2	0		2
180-189	2	1		3
190-199	4	0		4
200-209	8	1		9
210-219	14	5	6	25
220-229	12	9	8	29
230-239	17	18	23	58
240-249	24	45	39	108
250-259	31	39	45	115
260-269	32	40	40	112
270-279	34	37	38	109
280-289	35	42	37	114
290-299	14	28	34	76
300-309	20	33	26	79
310-319	22	24	30	76
320-329	18	20	27	65
330-339	10	25	28	63
340-349	7	18	9	34
350-359	11	11	13	35
360-369	4	8	14	26
370-379	3	9	7	19
380-389	1	4	6	11
390-399	3	5	5	13
400-409	1	7	2	10
410-419	1	3	3	7
420-429	1	3	0	4
430-439	0	2	1	3
440-449	0	1	1	2
450-459	0		1	1
460-469	0		1	1
470-479	2		1	3

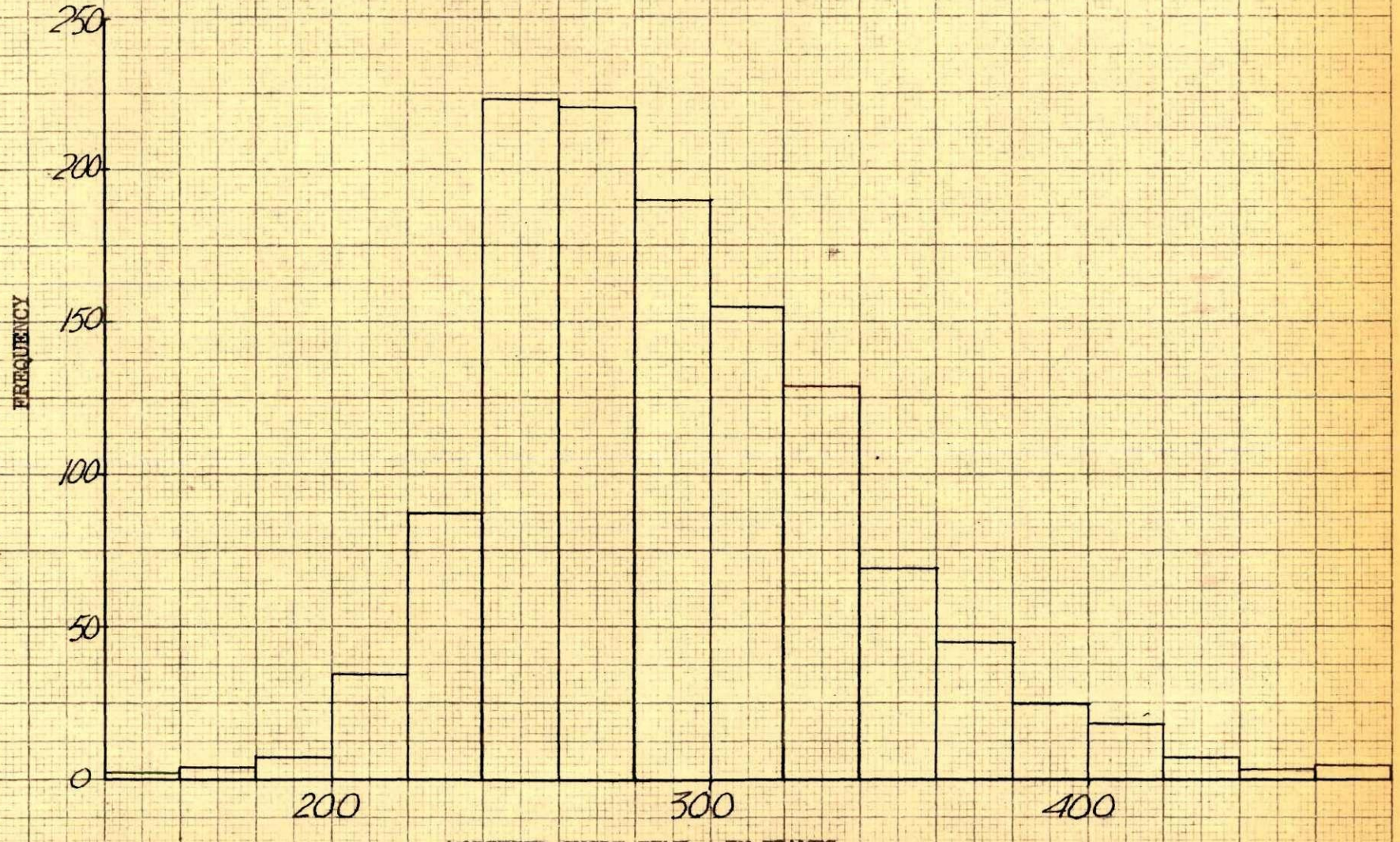


Figure 36. Operators 1-19 - All Shifts - Modified Cycle Time Histogram - No Variables Eliminated

Table 5. All Shifts - Modified Cycle Time Distribution - Variables Excluded

Modified Cycle Time in Frames	Shift No. 1 Operators 1-7	Shift No. 2 Operators 8-13	Shift No. 3 Operators 13-19	All Shifts Operators 1-19
150-159	1			1
160-169	0	1		1
170-179	1	0		1
180-189	0	0		0
190-199	0	0		0
200-209	0	1		1
210-219	1	0	3	4
220-229	1	3	4	8
230-239	4	5	7	16
240-249	4	15	13	32
250-259	3	14	18	35
260-269	4	12	14	30
270-279	5	10	8	23
280-289	3	7	9	19
290-299	0	5	3	8
300-309	0	6	5	11
310-319	0	5	4	9
320-329	2	5	4	11
330-339	1	0	3	4
340-349	1	2	0	3
350-359	2	0	1	3
360-369		2	2	4
370-379		2	0	2
380-389		0	1	1
390-399		0	0	0
400-409		0	1	1
410-419		0		0
420-429		0		0
430-439		1		1

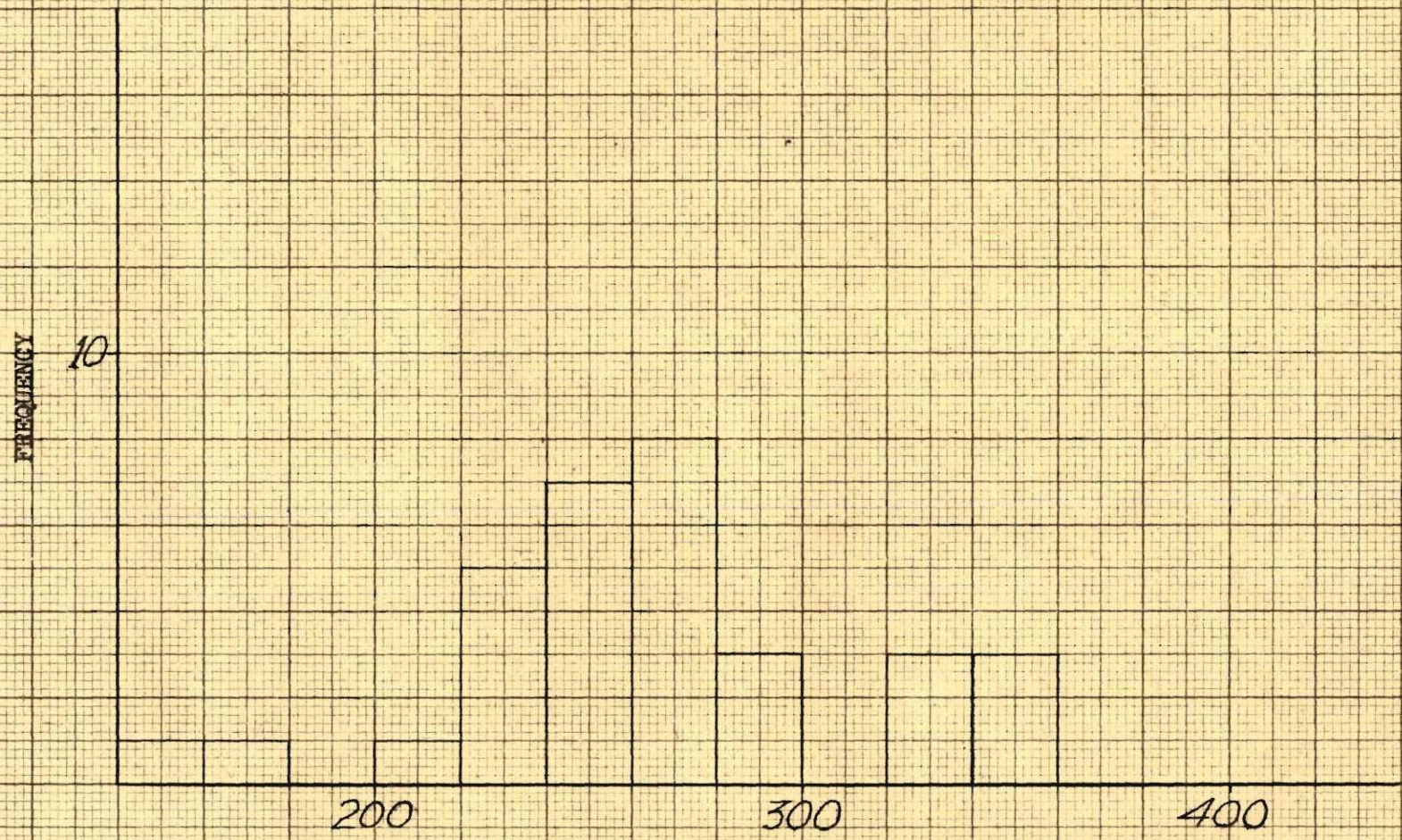


Figure 37. Operators 1-7 - First Shift - Modified Cycle Time Histogram - Variables Excluded

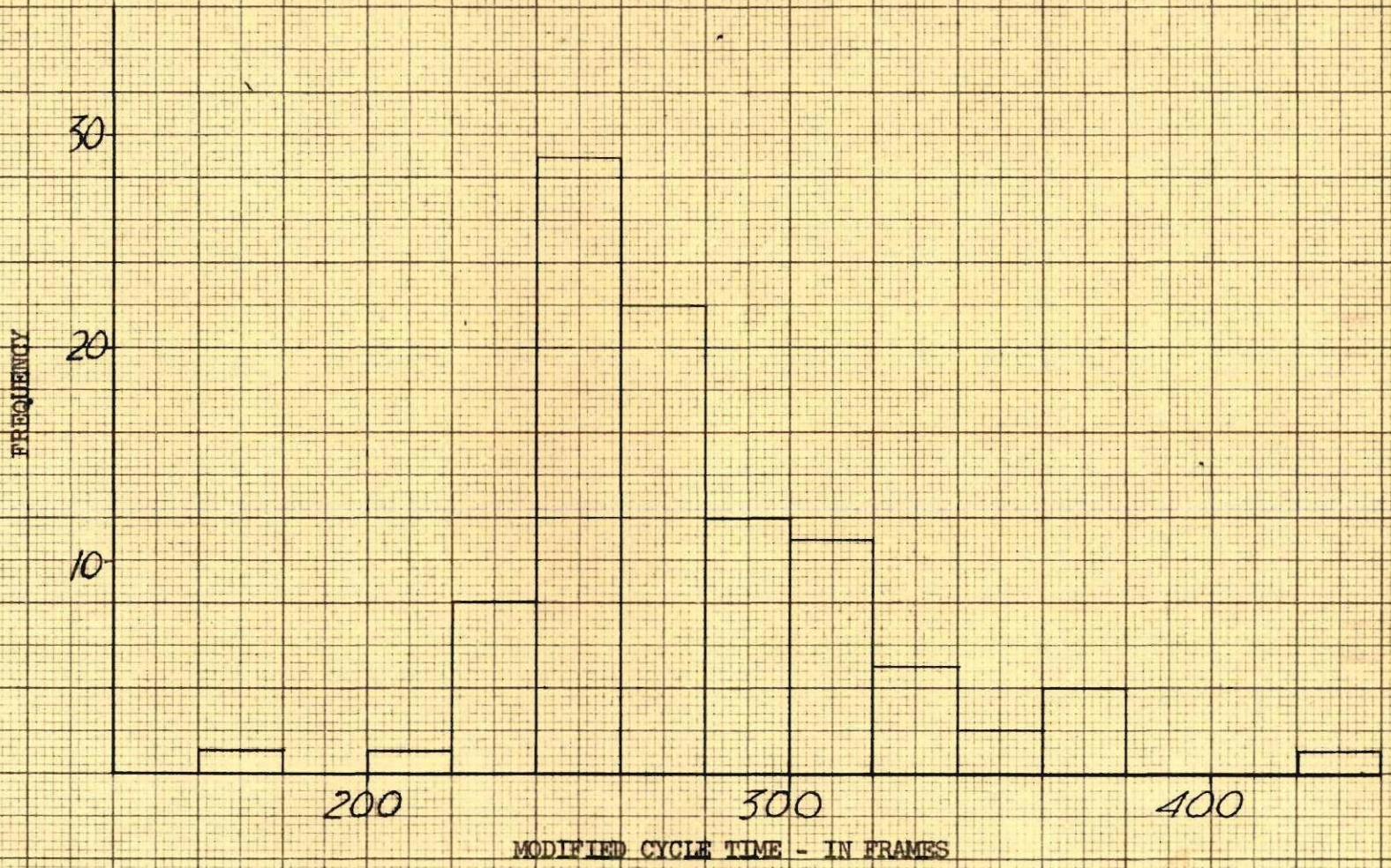


Figure 38. Operators 8-13 - Second Shift - Modified Cycle Time Histogram - Variables Excluded

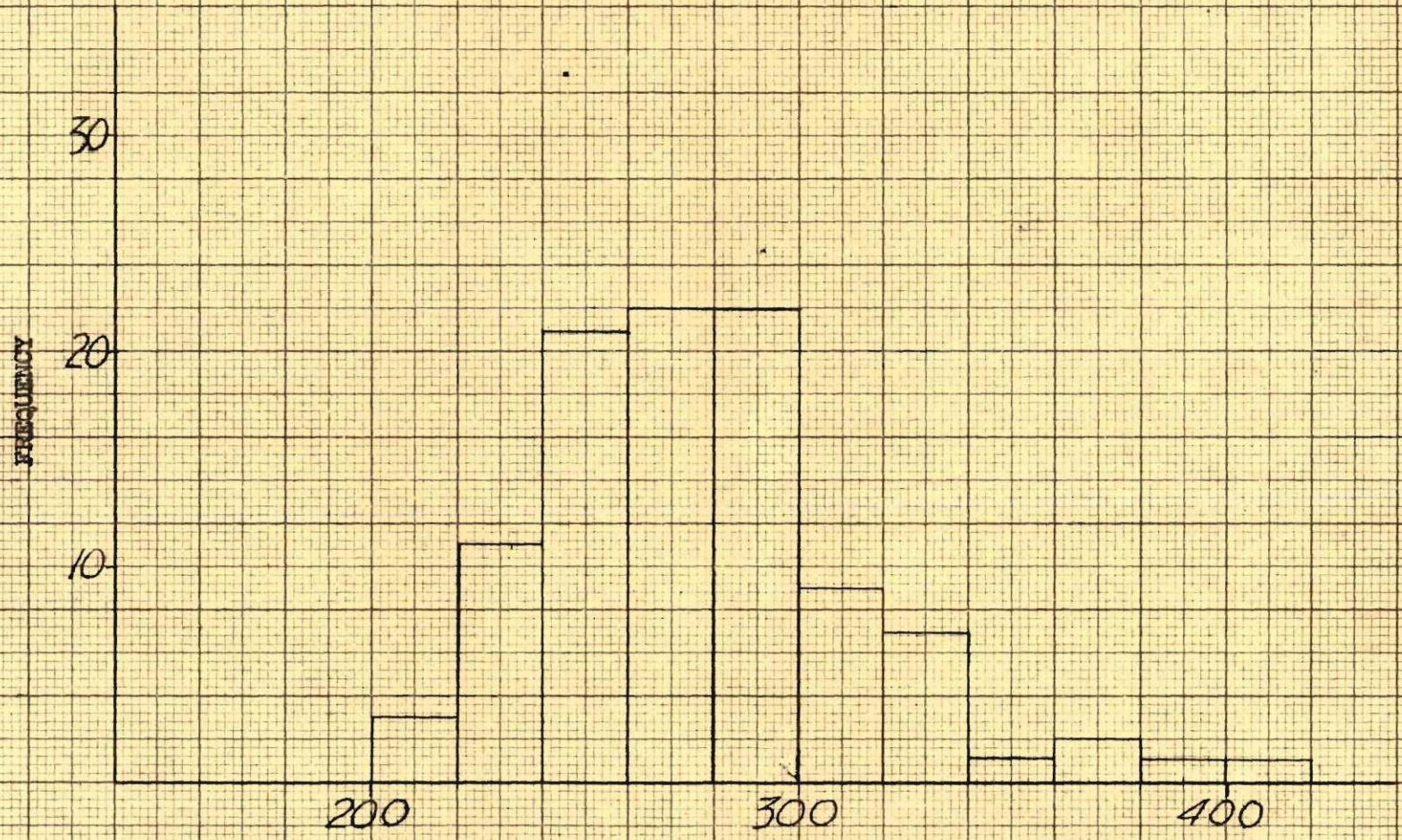


Figure 39. Operators 14-19 - Third Shift - Modified Cycle Time Histogram - Variables Excluded

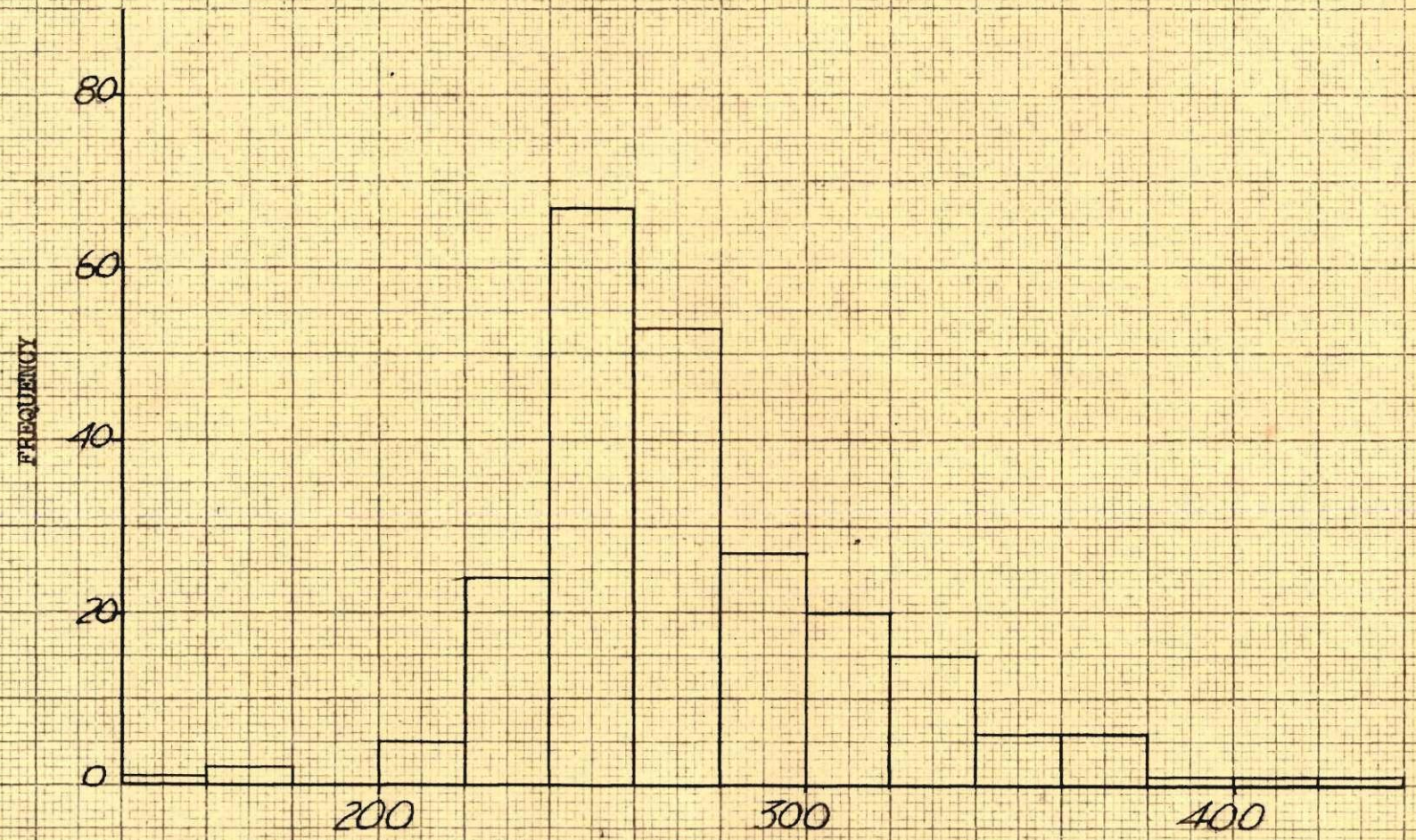


Figure 40. Operators 1-19 - All Shifts - Modified Cycle Time Histogram - Variables Excluded

Table 6. All Shifts - Gross Cycle Time Distribution - No Variables Eliminated

Gross Cycle Time in Frames	Total All Shifts	Gross Cycle Time in Frames	Total All Shifts
150-159	1	380-389	9
160-169	0	390-399	9
170-179	1	400-409	11
180-189	2	410-419	6
190-199	5	420-429	8
200-209	9	430-439	5
210-219	24	440-449	3
220-229	28	450-459	4
230-239	56	460-469	2
240-249	101	470-479	5
250-259	110	480-489	2
260-269	107	490-499	2
270-279	95	500-509	3
280-289	101	510-519	2
290-299	68	520-529	0
300-309	67	530-539	3
310-319	64	540-549	1
320-329	50	550-559	0
330-339	57	560-569	1
340-349	25	570-579	0
350-359	31	580-589	0
360-369	18	590-599	1
370-379	12		

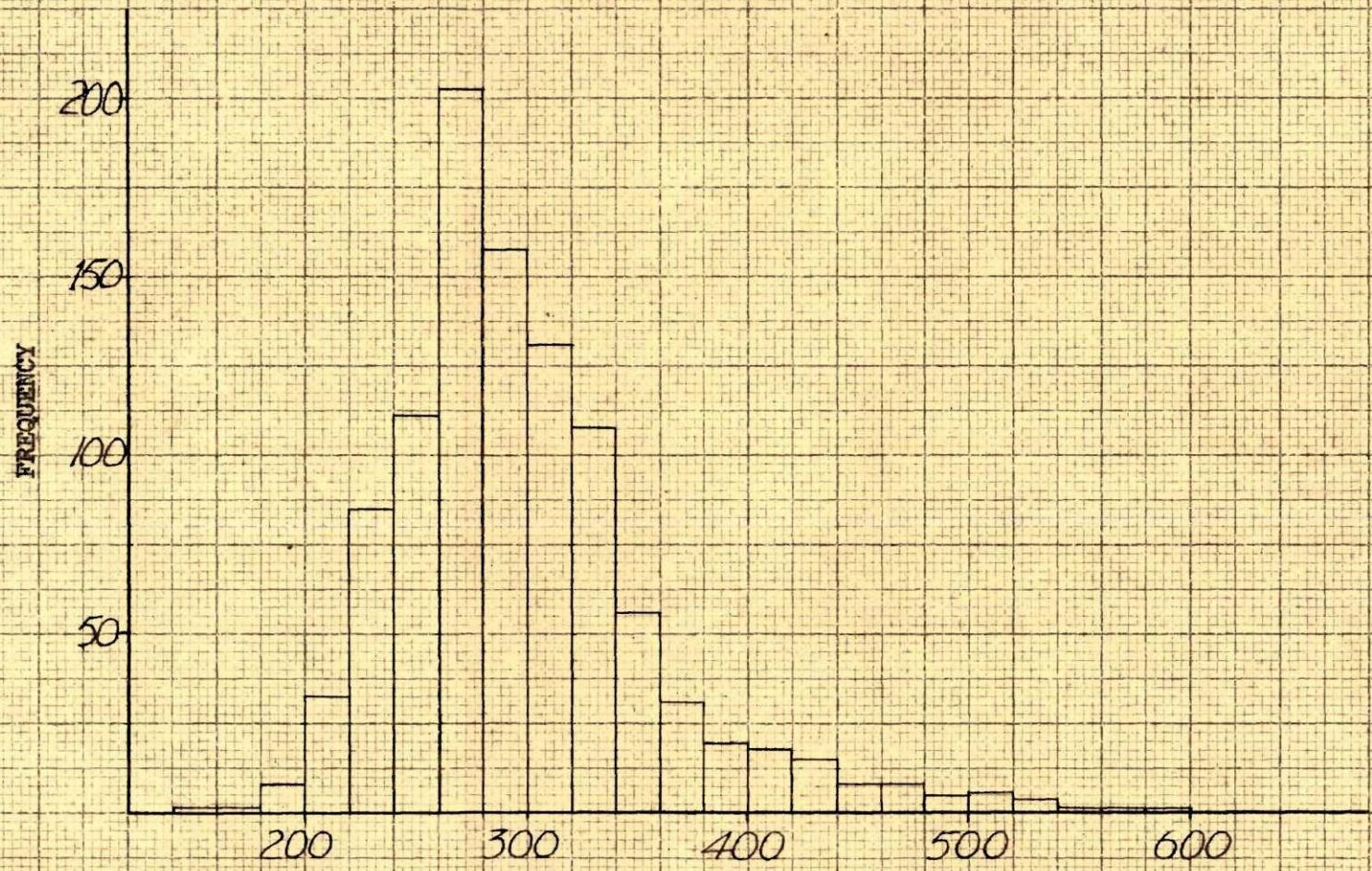


Figure 41. Operators 1-19 - All Shifts - Gross Cycle Time Histogram
No Variables Eliminated

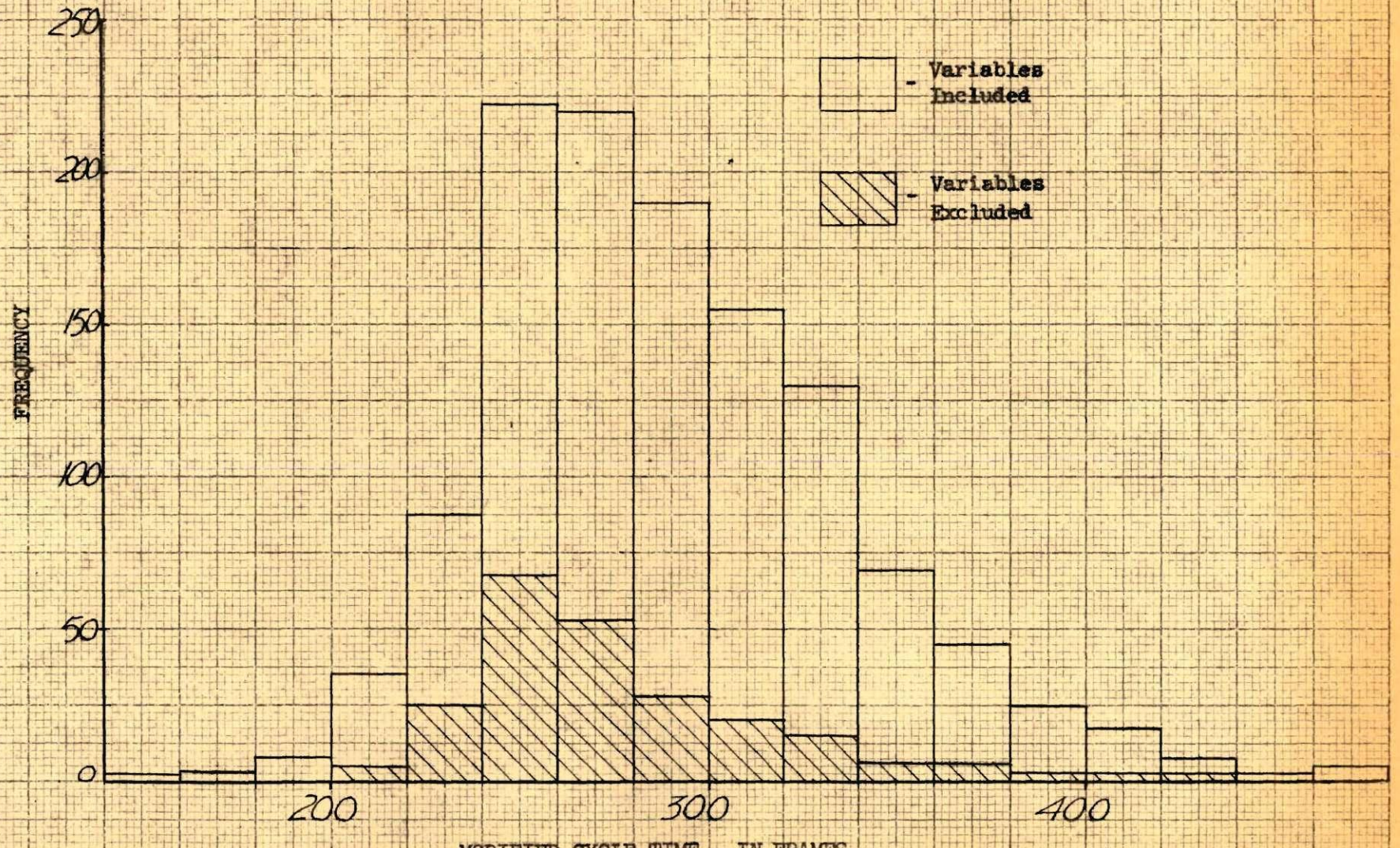


Figure 42. Operators 1-19 - All Shifts - Modified Cycle Time Histogram

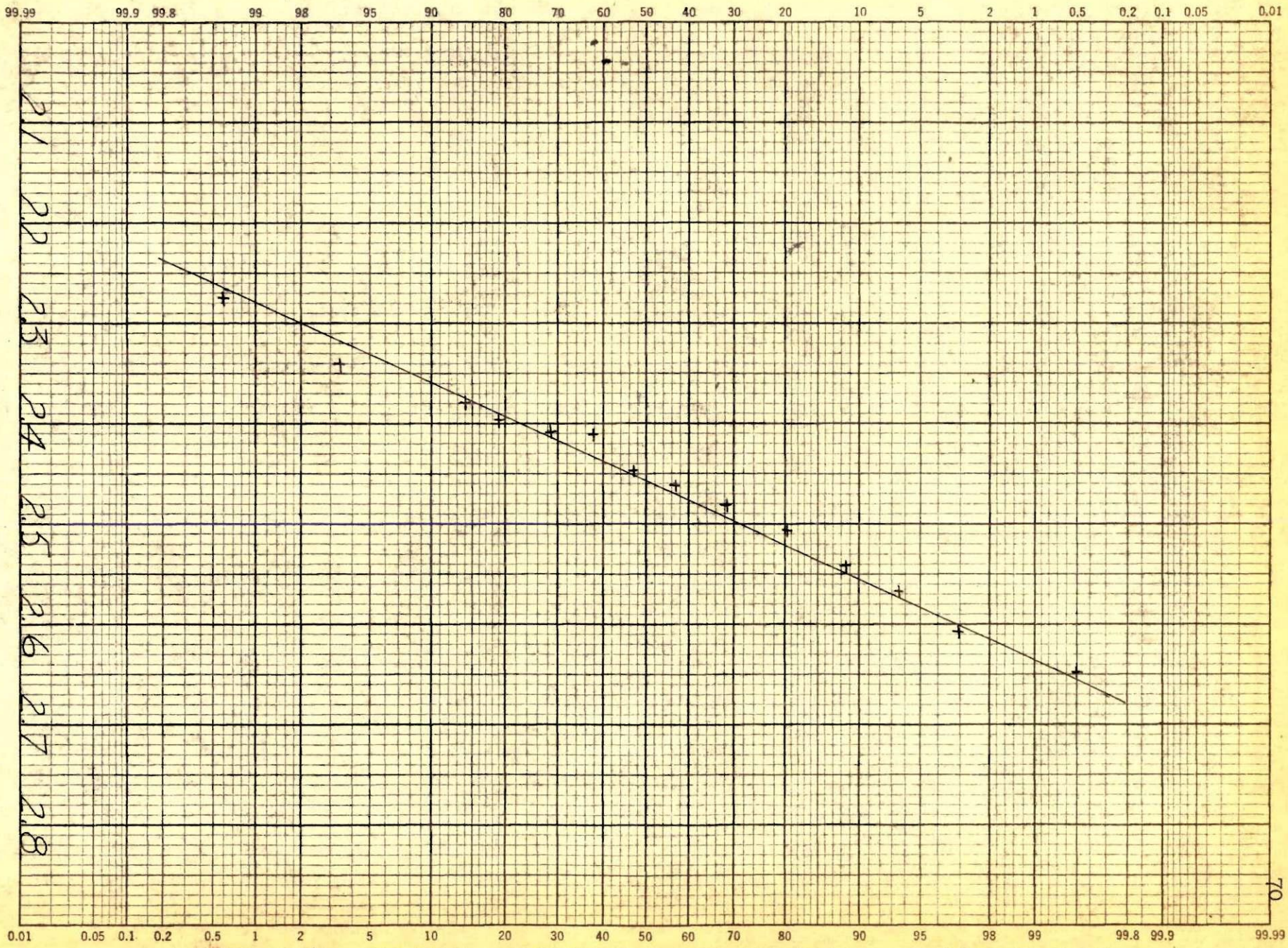


Figure 43. All Shifts - Modified Cycle Time Distribution - Variables Included
Probability Ruling

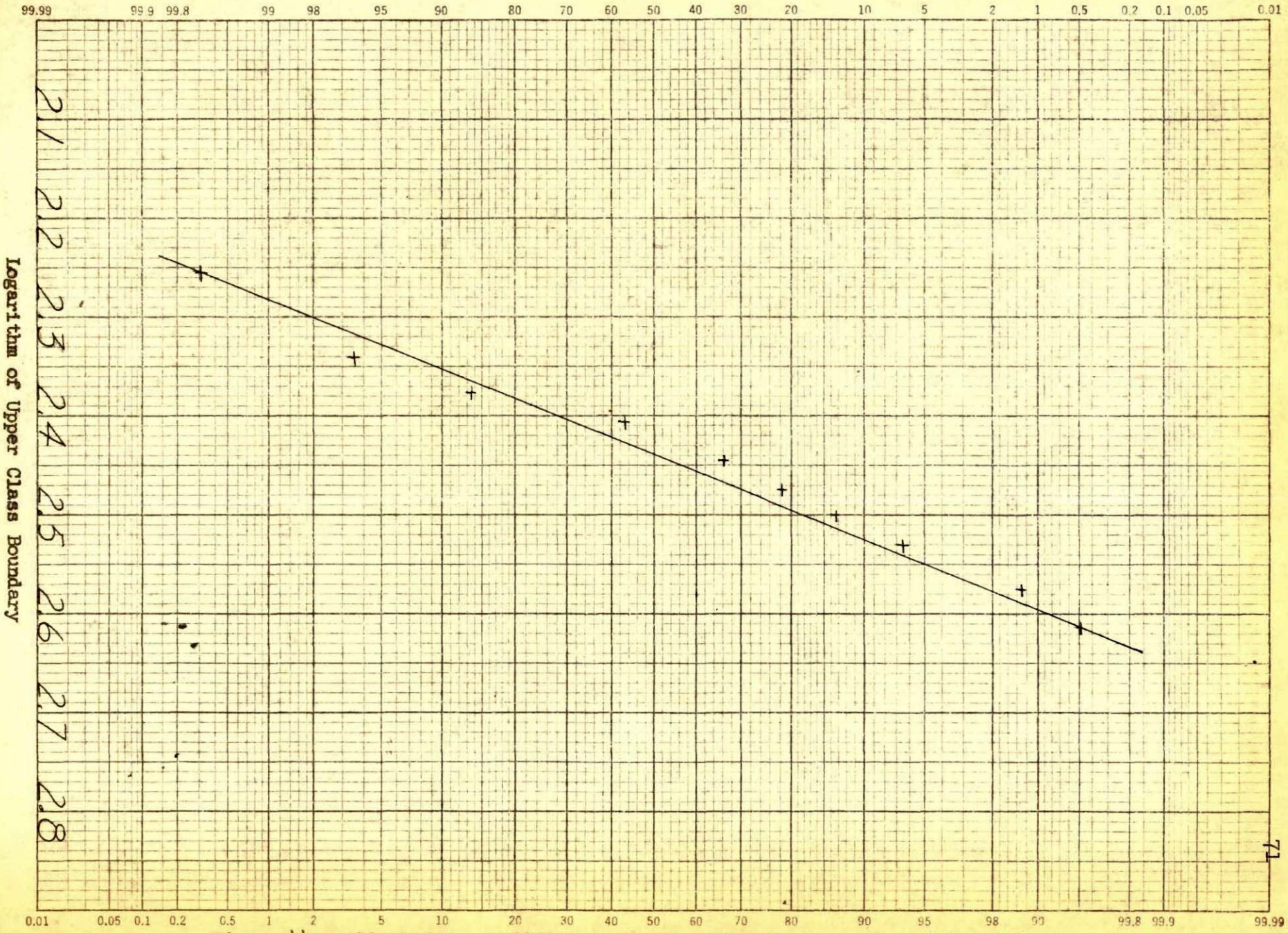


Figure 44. All Shifts - Modified Cycle Time Distribution - Variables Excluded
Probability Ruling

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

There are several controlling factors which accompany this study and they should be mentioned. They are:

1. The data covers only one operation in one plant.
2. Data were gathered from 19 operators.
3. A limited number of variables were classified.

Conclusions.--Considering the foregoing factors, the following conclusions were drawn:

1. The individual operator modified cycle time distributions with variables included tend to be positively skewed.
2. The shift distributions with variables included and variables excluded are positively skewed.
3. The distribution of all shifts combined with variables included and variables excluded are positively skewed.
4. The modified cycle time distribution, with variables included and variables excluded, approximated a straight line relationship, when the log of the cycle time was plotted on probability paper; thus the distributions can be approximated by a log normal curve.

Recommendations

A visual examination of the all shifts distributions indicates that a more detailed classification of variables is necessary to distinguish assignable causes of variation within the work cycle.

It is recommended that a similar study be made classifying the variables within the individual elements. A study of this nature would necessarily require a re-analysis of the film and a reclassification of

variables determined by the elemental behaviors.

A study of this nature would provide a real insight into the validity of many timing practices used in industry. It also could serve as a basis for accepting, rejecting or refining many of the time systems presently used.